EVALUATION OF MAP SYMBOLS FOR A COMPUTER GENERATED TOPOGRAPHIC DISPLAY: TRANSFER OF TRAINING, SYMBOL CONFUSION, AND ASSOCIATION VALUE STUDIES

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ANACAPA SCIENCES, INC.
P. O. DRAWER Q.
SANTA BARBARA, CA 93102
TELEPHONE (805) 966-6157

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This report describes three studies conducted to evaluate the effectiveness of map symbols for a computer-generated topographic display. The criteria for developing symbol effectiveness were transfer of training, potential confusion, and association value.

A computer-generated topographic display, or CGTD, utilizes a cathode ray tube (CRT), or other electronic display, to present map-like information. Conventional map symbols often are inapplicable with a CGTD because the

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matrix of display elements, or "pixels" does not provide sufficient resolution for portraying small and detailed shapes. As a part of the research described in this report, design guidelines were developed for creating symbols that meet the limitations of a pixel matrix display. Sixty-nine topographic and tactical symbols were developed for the candidate symbol set.

The evaluation of symbol effectiveness was conducted by means of three surveys completed by military personnel. In Task One, the participants compared the map symbols in the candidate set with the symbols in the current set to determine if similarities existed. Because the participants could view both symbol sets in their entirety, the matching task was the analog of a transfer of training study in which the participants had "perfect recall." Similarity of a candidate symbol and its intended current symbol indicated positive transfer of training, while similarity of a candidate symbol and an unintended current symbol indicated negative transfer of training.

In Task Two, the participants compared symbols within the candidate set to determine if similarities existed. Similarity of any two symbols indicated potential for confusion.

In Task Three, the participants matched verbal definitions with candidate symbols. The frequency with which a candidate symbol was paired with its intended verbal definition is operationally defined as the symbol's association value. Symbols paired with their intended definitions had positive association value.

Numeric scores for each candidate symbol were derived from the survey data. Quotients for the three criteria--transfer of training, potential confusion, and association value--provided a means for evaluating the effectiveness of the candidate symbols. The results provided reasonably clear distinctions among classes of symbols.

Recommendations are provided for evaluating and modifying individual symbols.

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Technical Report 459-5

Christopher J. Jarosz
and
Steven P. Rogers

Submitted to:

ADVANCED SYSTEMS DIVISION (DAVAA-F)
U.S. Army Avionics R&D Activity
Fort Monmouth, New Jersey 07703

Submitted by:

ANACAPA SCIENCES, INC.
P.O. Drawer Q
Santa Barbara, California 93102
(805) 966-6157

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FOREWORD

The studies described in this interim report were performed as partial fulfillment of the requirements of Contract No. DAAK80-81-C-0089, issued by the U.S. Army Communications Research and Development Command, in support of the Avionics R&D Activity at Fort Monmouth, New Jersey. These studies form part of a larger research program being conducted to support the development of computer-generated topographic information systems employing electronic display devices. A graphic overview of the major activities in this research program is shown in Figure A.

Interim reports have been issued for Phases 1 and 2 (Rogers, 1982), Phase 3 (McCallum and Rogers, 1982), Phase 4 (Rogers, Gutmann, and Ralstin, 1982), and Phase 5 (Gutmann and Rogers, 1982), although work continues on Phases 4 and 5. The present report describes research performed during Phase 6, the evaluation of symbol comprehensibility. Although Phase 6 will continue, this report describes the major portion of the research -- the study of transfer of training, association value, and confusability of map symbols developed for use with electronic display systems.

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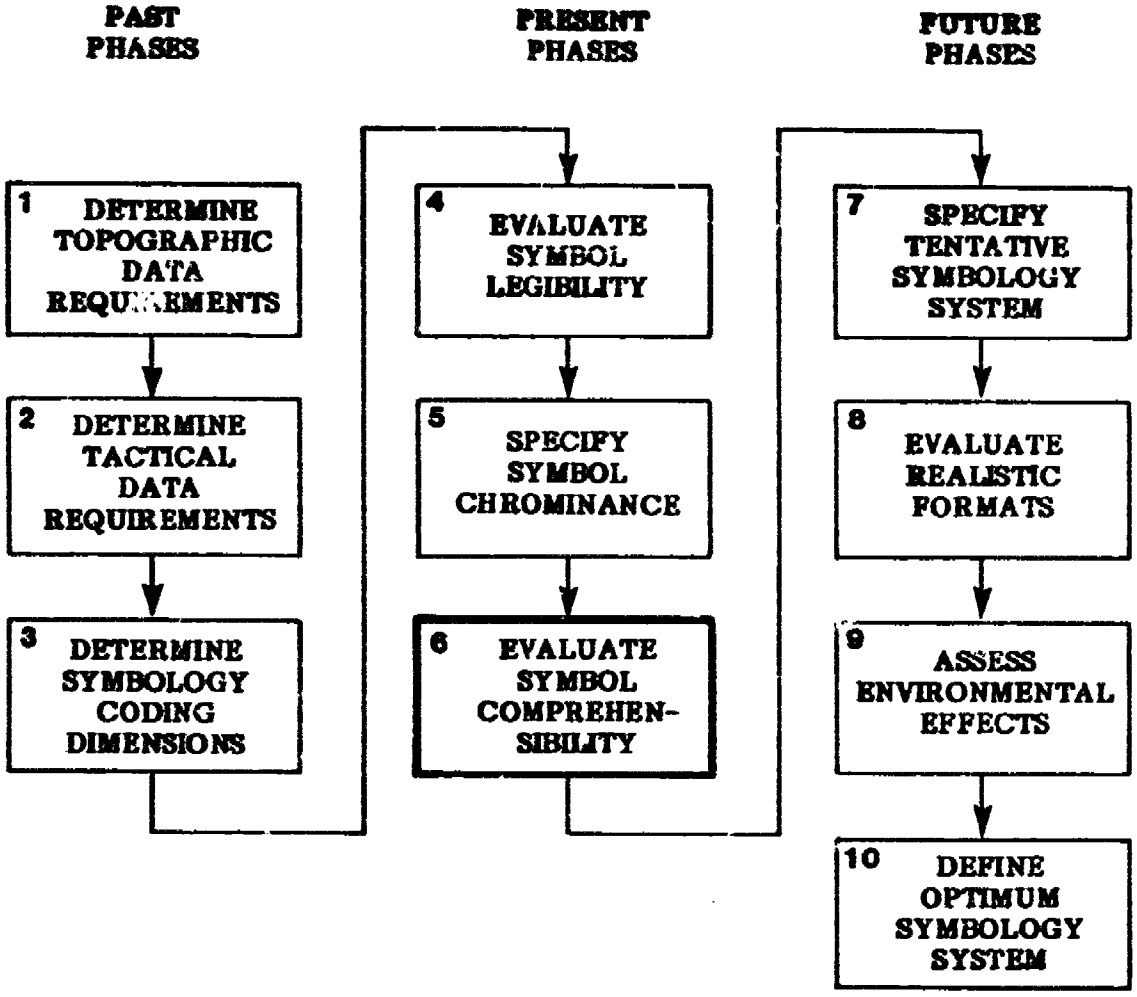

Figure A. Overview of the phases of the research effort performed under Contract DAAK80-81-C-0089. The phase described in this interim report is indicated by the bold-lined rectangle.

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SECTION I.
INTRODUCTION

This report describes the initial phases in the development and evaluation of topographic and tactical symbols for computer-generated maps for use by Army aviators. This section of the report describes the background leading to the symbol development effort, the research objectives, and the organization of the report.

BACKGROUND

Army Aviation Tasks

During the past three decades, Army aviation has been tasked with an ever-broader range of missions. Today, helicopters are an integral component of the combined arms team and perform a great variety of tasks. Army aviators must be prepared to enhance the ground commander's capabilities in one or more of the five functions of land combat: firepower, mobility, intelligence, command and control, and combat service support. Furthermore, Army aviators are expected to provide a rapid response over a wide area of operations. Thus, as the aviators' responsibilities have grown, the time available for their performance has diminished. Nevertheless, aviators are expected to plan and conduct their missions with great precision and maintain accurate geographic orientation at all times. These demands are particularly formidable because of the extremely low altitudes of flight required for survival in the high-threat environment.

Map Use in Army Aviation

Map use in support of Army aviation consists of several distinct categories of activity. Three of these activities -- mission planning, navigation, and tactical decision-making -- are briefly described in the following paragraphs.

Mission Planning

Extensive mission planning activities are required of the Army aviator. The successful accomplishment of many of these activities depends upon the aviator's ability to extract information from maps. At a minimum, the aviator must study

and visualize the overall situation and topography; select engagement points, observation points, and landing zones; determine primary and alternate (masked) routes of flight; select air control points, checkpoints, and barrier features; and determine flight techniques, altitudes, speeds, and durations.

Navigation

Given the nature of the high threat environment, it is unlikely that aviators will be able to make use of radio navigation aids. Dead reckoning (computing direction and distance from a known position) is unreliable given the sinuous course and variable speed of NOE flight. Thus, navigation must often be performed only by "pilotage" -- by identifying visible landmarks, and correlating them with features depicted on the map.

Tactical Decision-Making

Use of maps for tactical decision-making and the communication of these decisions are tasks performed not only during the mission-planning phase, but also during and after the flight mission. Examples of tactical factors to be considered before flight include the study of fields of fire, trafficability of terrain, and required techniques of terrain flight (low-level, contour, or NOE). During flight, aviators may be required to communicate their position or the position of targets to infantry units, artillery units, attack helicopters, or high-performance aircraft. Maps are also used for intelligence summary. For example, enemy disposition, strength, and associated data are noted on the map during flight, consulted during post-flight debriefing sessions, and employed in pre-flight preparations for subsequent missions.

Difficulties in Map Use

Maps create problems for all users because they do not and cannot represent a true picture of the real world. Instead, they are schematic diagrams -- stylized, simplified, generalized, and codified presentations of a selected sample of some of the characteristics of the earth's surface. In addition to this general problem, Army aviators must deal with three particular difficulties involving scale, handling, and content.

Scale Problems

Army aviators must use 1:50,000-scale maps because maps in this scale provide the level of detail necessary for maintaining geographic orientation when flying at low altitudes. Unfortunately, these maps are unavailable for large areas of the earth's surface, and their compilation, revision, and production require very long lead times. As a result, aviators may be forced to use out-of-date 1:50,000-scale maps, or to use 1:250,000-scale maps that provide insufficient detail.

Handling Problems

Maps are cumbersome when used in aircraft cockpits, especially when they must be annotated, refolded, and registered with overlays. Because 1:50,000-scale maps depict only an area of about 25 by 27 kilometers, they must be frequently exchanged for other maps during the course of a mission, resulting in additional handling problems.

Content Problems

Because of the high cost of producing paper maps, virtually all products of the Defense Mapping Agency are designed to serve the needs of several different classes of users. It is nearly impossible to produce maps with all the information desired by all potential users without cluttering the maps beyond the point of legibility. Consequently, some compromises are made in the information content of a map, so that each class of user is likely to find the map deficient in some manner. Even a map designed specifically for Army aviators could not present all of the potentially useful topographic information because of the clutter problem, and the cartographer is forced to make judgments regarding the items of information best omitted.

In addition to their topographic content, maps are annotated with tactical information. Aviators have found that annotations written directly on the map must be limited in number if the topographic information is to remain unobscured, and that a limited amount of annotation is possible with overlays.

The Computer-Generated Topographic Display

A computer-generated topographic display system (CGTD) is currently under development by the Advanced Systems Division of the U.S. Army Avionics R&D Activity (Rogers, 1981). A CGTD system using a cathode ray tube (CRT) display will solve the problems of scale, handling, and content, and could provide dramatic improvements in cartographic support, map-oriented computations, and aviator-map interactions. For example, the computational capability of the CGTD could be used to:

- Change the scale of the displayed map to that optimal for the momentary needs of the aviator.
- Employ small tape cassettes that can each store terrain data equivalent to the data depicted on sixteen 1:50,000-scale maps.
- Show the general lay of the land by use of shaded elevation bands to indicate high and low areas.
- Present a shaded "relief map" enhanced by contour lines.
- Display areas masked from visual or radar observation given known or likely enemy positions.
- Construct oblique, perspective views of terrain to familiarize the aviator with the landforms in the battle area.
- Perform navigational computations pertaining to airspeed, groundspeed, and elapsed time over a given flight route.
- Interact with a terrain correlation navigation system similar to the system used in cruise missiles. This system is small, self-contained, lightweight, accurate in all weather conditions, and essentially invulnerable to countermeasures.

The CGTD will also provide operator control over the content of the displayed information. First, the aviator will be able to annotate the cassette with planned course lines, checkpoints and other data, either at a mission-planning console or in the aircraft. Second, the aviator will be able to select any combination of topographic features and tactical information. Thus, he will be

able to design an optimal map display for mission-planning and in-flight use for any type of terrain or battlefield situation. Aviators will be given control of the classes of information that are displayed (such as vegetation or hydrography) and the criteria for selecting specific features of a given class (such as deciduous trees or perennial streams). Various overlays and annotations can be displayed or rapidly deleted to clarify the underlying topographic data. Because the aviator will control the feature-selection rules, he will also be able to control the density of displayed information to eliminate disruptive clutter.

Map Display Resolution Problems

The symbology currently used on paper maps is not, in most cases, suitable for presentation on computer-generated CRT or flat-panel electronic displays since the resolution of these devices is only a fraction of that obtainable with paper maps. For example, the format may appear needlepoint-like and "grainy," as shown in Figure 1. This figure approximates the appearance of a portion of a 240 x 240 element (or pixel) matrix on a large TV screen. On smaller CRT screens that are appropriate to aircraft cockpit use, the apparent graininess would be reduced, although not eliminated. Although a map display would not be required to show portraits of human beings, as in Figure 1, the same "stairstep" effects would interfere with the portrayal of straight lines not aligned with the raster, and limit the portrayal of curved lines.

One way to examine the resolution limitations of a pixel matrix is to compare minimum symbol sizes available from such a display with the sizes of symbols currently employed on standard topographic maps. If a 240 x 240 pixel map is presented on an 8 x 8 inch screen, for example, the pixels will consist of squares measuring .85mm on a side. This pixel size can easily fit inside the letter "o" in the type font used in this report. However, this seemingly small element compares unfavorably with the dots achievable by printing on paper maps -- about .10mm.

Figure 1. Example of the unusual appearance of a pixel-matrix display.

The difference in ability to resolve fine detail is particularly apparent when one considers small spot symbols such as that used to depict a church (⛪). On a standard topographic map, this symbol is about .8mm wide and 1.6mm tall. On the pixel matrix described above, the area of the church symbol would be equal to two pixels. Adequate definition of the symbol would require many more pixels and a much larger symbol, as shown in Figure 2.

Figure 2. Construction of a church symbol from pixels.

Problems in symbol-portrayal become even more difficult when symbols employ diagonal or curved lines since the normal configuration of these figures cannot be presented in a pixel matrix. Thus, the symbols must be made very large to approximate the contours of the symbol. For example, consider the attempts to construct the propeller-shaped Army aviation symbol from pixels shown in Figure 3. At the left is a normal size for the symbol. To the right are three attempts to render the propeller shape in a pixel matrix. The most successful attempt, at the far right, is still not a particularly effective symbol, although it occupies about 70 times the map area required for the printed version.

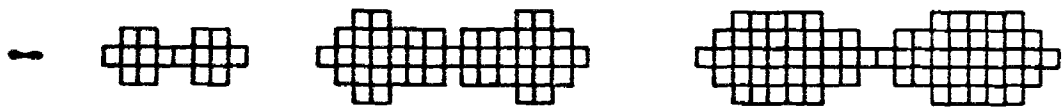


Figure 3. Attempts to construct a propeller shape from pixels.

The pixel-matrix format affects alphanumeric characters as well as lines and point symbols. First of all, letters composed from a pixel matrix are not as clear as those normally printed on paper. Second, the letters (like other symbols) must be considerably larger than those printed on paper.

The various display resolution problems discussed in this section might seem to make the production of topographic maps nearly impossible. It is important to remember, however, that producing copies of existing paper maps is not the goal of a CGTD. Given the fundamental differences between paper maps and computer-generated maps, there are at least four reasons for not slavishly duplicating paper map content and format on a CRT screen.

First, not all of the content of the standard military topographic map is necessary to the Army aviator. Research by McGrath, Osterhoff, and Borden (1964) suggests that place names on maps contribute almost nothing but clutter,

and actually interfere with navigation in high-speed, low-altitude flight. Conceivably, significant amounts of topographic map content may be only minimally useful to Army aviators. Second, the format of existing paper maps may be altered without loss of information. If current symbology is not adequate for pixel-matrix displays, it must be revised to meet the new requirements. Third, the CGTD has a distinct advantage over paper maps since not all information needs to be presented simultaneously. The user of the CGTD will be able to control map clutter by deleting all but the information required at any given moment. Fourth, the computer system can perform certain calculations that will eliminate the requirement for map overprint information. For example, coordinates of positions, and distances between points will be provided automatically (upon query by light pen or cursor), eliminating the basic requirement for a numbered grid system.

In summary, although the limited resolution of the pixel-matrix display does pose some problems for the design of CGTD symbology, these obstacles can be overcome through the conduct of a well-reasoned research program.

MAP SYMBOL DESIGN REQUIREMENTS

Although the field of human information processing has received intensive study for the past two decades, little of this research has been directly applicable to map symbol design (Rogers, 1981). Nevertheless, it is certain that there are at least three requirements for the development of new map symbols:

- Positive transfer of training from previously used symbols,
- Minimal confusion among new symbols, and
- Maximal association value of new symbols with their intended meanings.

Transfer of Training

To the extent possible, CGTD symbology should provide good transfer of training from existing paper maps. One way of looking at the transfer-of-training problem is via the transfer surface concept proposed by Osgood (1949). This concept has been adapted in Figure 4 to show transfer as a continuous function of the degree of similarity of two symbols (paper map and CGTD) and the similarity

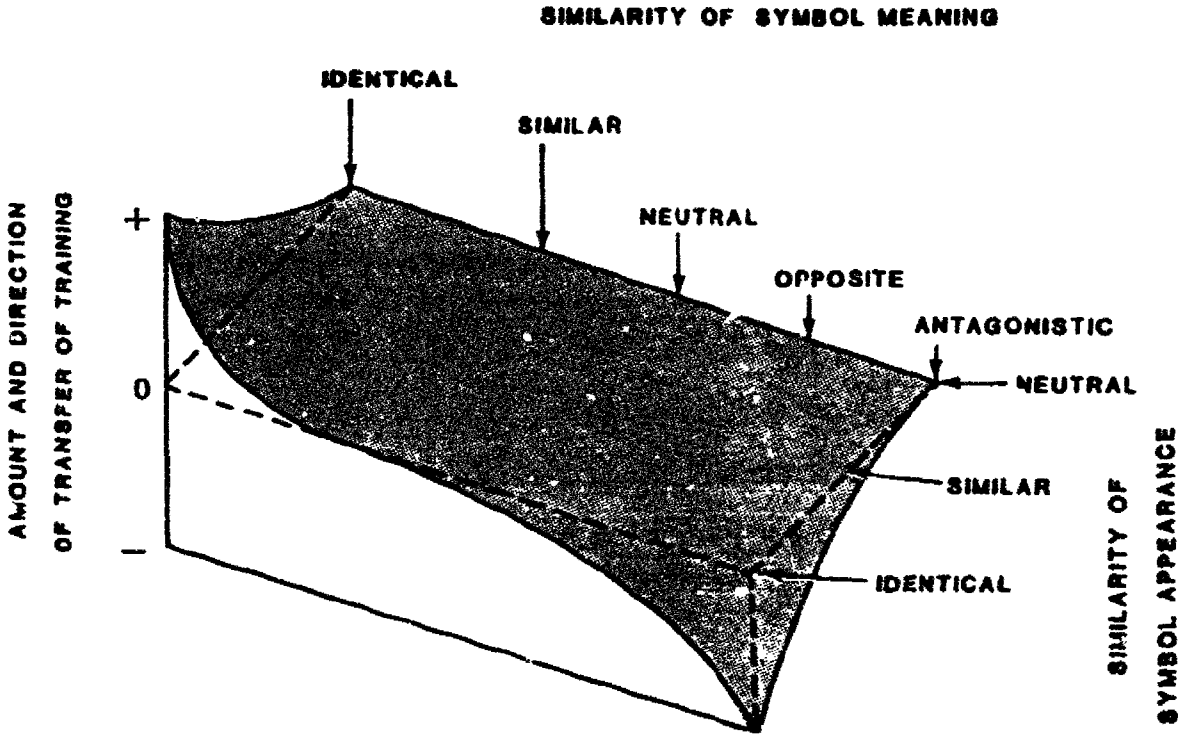
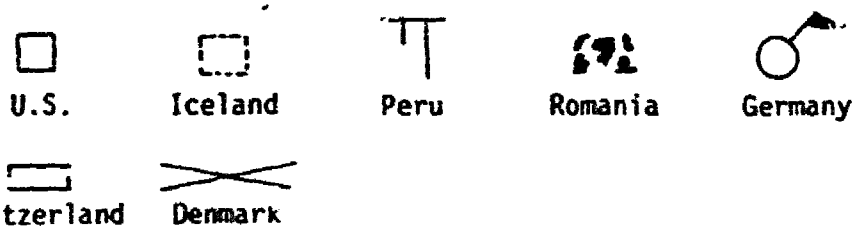


Figure 4. The transfer surface.

of their verbal meanings. The amount of positive (or useful) transfer is maximum when both the appearance and meaning of a CGTD symbol is identical to that of the paper map symbol. No transfer occurs when the CGTD and paper map symbols have an identical meaning but dissimilar appearance. The greatest amount of negative (confusing) transfer takes place when the paper map and CGTD symbol appearances are identical, but their meanings are dissimilar or antagonistic. Since CGTD symbology does not yet exist, examples of zero and negative transfer of training can be provided by comparing U.S. and foreign maps. Comparisons for cultural features are shown in Figure 5.

ZERO TRANSFER OF TRAINING (Same meaning, different symbols)

MEANING	SYMBOLS
LIGHTHOUSE	 U.S. Germany Denmark
CHURCH	 U.S. Germany Molukken Islands Algeria Denmark
TELEGRAPH STATION	 Algeria Norway Vietnam Peru Romania
RUINS	 U.S. Iceland Peru Romania Germany Switzerland Denmark

NEGATIVE TRANSFER OF TRAINING (Same symbol, different meanings)

SYMBOL	MEANINGS
	School (U.S.), Border Patrol Post (Romania)
	Ruins (U.S.), Farm (Norway)
	Submerged reef (U.S.), Sunken rock (Greenland), Boundary marker (Austria), Church (Denmark)
	Telegraph (Algeria), Train stop (Denmark), Filling station (Germany)
	Tower (U.S.), Trig point (Germany), Chimney (Austria), District office (China), Lighthouse (Norway), Tower (Bahrain), Monument Denmark), Coffee field (Molukken Islands)

Figure 5. Examples of zero transfer and negative transfer of training for cultural feature symbology used on foreign maps.

Symbol Confusion

Symbols with entirely different meanings should be sufficiently different in appearance to minimize potential confusion by map users. For the current research effort, symbol confusion refers to the inability of map users to distinguish among symbols on a consistent basis, given that the symbols are legible from a normal viewing distance. Failure to consider potential confusion when designing symbols for the CGTD is likely to result in a symbol set that does not convey information required for Army aviation tasks. For example, confusion of symbols for enemy tanks and air defense weapons could be disastrous for the aviator.

Related symbols, such as symbols for classes of tanks or air defense weapons, may require some similarity to facilitate rapid identification and classification. This practice is currently used in cartographic design of symbols, as shown in Figure 6.

Light Tank Medium Tank Heavy Tank

Figure 6. Similarity/dissimilarity of military symbols for classes of tanks (FM 21-30, 1970).

Association Value

Symbols should be readily associated with their intended verbal meanings to reduce training time and likelihood of misinterpretation. The degree to which a symbol suggests its verbal meaning is known as its association value. The value can be positive, negative, or zero, depending on whether the symbol is associated with its intended meaning, an unintended meaning, or no meaning on a consistent basis. Examples of the types of association are shown in Figure 7 for the symbol used for a church on paper maps.

Type of Association	Symbol	Verbal Meaning
Associated with intended meaning		Church
No consistent association		Church, School, Lighthouse
Association with unintended meaning		Lighthouse

Figure 7. Three types of association between verbal meanings and a map symbol.

Several factors help to determine association value. For example, if there is high transfer of training from the current symbol, experienced map users are likely to associate the new symbol with its intended verbal meaning. Commonly used abbreviations for objects and pictorial symbols that convey likenesses of objects are also likely to have high association values. Examples of these symbols, although relatively rare on conventional paper maps, are shown in Figure 8.

Post Office

Exposed Wreck

Figure 8. Examples of symbols containing an abbreviation and a pictorial likeness that are strongly associated with their intended verbal meanings.

In summary, map symbols for the CGTD will ideally have high transfer of training from conventional paper map symbols, low potential for confusion, and high association with their intended verbal meanings. In actuality, many symbols might not meet all of these criteria. The selection of a final set of symbols for the CGTD will be based on a careful evaluation of the tradeoffs in meeting the three criteria.

RESEARCH OBJECTIVES

The general objective of the research described in this report was to develop symbols for a CGTD to meet Army aviation requirements. The specific objectives of this research were to:

- Design a candidate set of symbols for Army aviation uses that meet the constraints of a CGTD.
- Determine the degree of transfer of training from the current set of symbols for paper maps to the candidate set for the CGTD.
- Determine the potential for confusion among symbols within the candidate set.
- Determine the levels of association between the candidate symbols and their verbal meanings.
- Identify candidate symbols requiring modification.

ORGANIZATION OF THIS REPORT

The subsequent sections of this report describe the design and evaluation of symbology for the CGTD. Section II provides a summary of past efforts to develop and evaluate map symbols on a systematic basis and the pertinence of these efforts to the present research. Section II also describes the guidelines used in developing pixel matrix symbols for the CGTD.

Section III describes the method for evaluating the transfer of training and potential confusion of the proposed symbology for the CGTD. In brief, the method involved administering a survey consisting of symbol-matching tasks to military personnel. Section IV describes a similar method for evaluating symbol association with verbal meanings. A summary of results and description of the computation of numeric indices to evaluate symbol effectiveness are presented in each section. Section V provides a discussion of the findings of the research project, and Section VI presents the project summary and recommendations.

Appendices I and IV contain examples of the survey booklets used to collect data for the three symbol evaluation techniques. The response distributions for these criteria are contained in Appendix II (transfer of training), Appendix III (symbol confusion), and Appendix IV (symbol association).

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SECTION II.
MAP SYMBOL DEVELOPMENT

This section describes the visual coding techniques applicable to the CGTD, a review of past research efforts to develop map symbols on a systematic basis, design guidelines for developing symbols for the CGTD, and an approach to evaluating symbol effectiveness.

APPLICABLE CODING TECHNIQUES

McCallum and Rogers (1982) conducted a review of previous research to identify visual coding dimensions that could be used for map symbols on a CGTD. Ten dimensions were identified: shape, alphanumerics, size, numerosity, inclination, brightness, color, flash rate, stereo depth, and apparent movement. Of these dimensions, only shape and alphanumerics (which can be considered to be a form of shape coding) were found to provide a sufficient number of coding steps to provide for adequate discrimination among map symbols. For example, the maximum number of pictorial and geometric shapes that can be distinguished is virtually unlimited, while only five to ten features can be distinguished using other coding methods, such as flash rate or movement. For alphanumeric combinations, the number of distinguishable features is also virtually unlimited. Coding dimensions may, of course, be combined (such as color and shape) for additional information transmission.

PREVIOUS RESEARCH IN MAP SYMBOL DEVELOPMENT

A literature review was conducted to identify previous efforts to develop map symbol shapes on a systematic basis. There were two purposes for this review. The first purpose was to attempt to identify guidelines that could be adapted to the development of map symbols for the CGDT. The second purpose was to evaluate experimental methods that have been used to study the effectiveness of the symbols.

In an early effort, Kaponen, Waters and Orlansky (1952) devised a technique for developing and evaluating map symbols for aeronautical charts. In the first

task, Navy pilots were asked to draw symbols for a variety of objects (such as oilfield, airport, and factory) for each of the following criteria:

1. Pictorial Likeness: Representations intended to look like or describe the entire object.

2. Part of the Whole: Any recognizable part of the entire object.

3. Verbal: Any word, abbreviation, letter, or combination of these that the subject associates with the object.

4. Related Object: An object which is in some way associated with, but not a part of, the original object.

5. Geometric: Representations that do not look like the original objects.

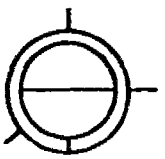
Very few of the symbols that were drawn by the aviators resembled the symbols portrayed on aeronautical charts. The "best" symbol for each object was determined by selecting the most frequently occurring version. In general, this led to the selection of symbols portraying pictorial likenesses of objects. In the second task, high school students were asked to match the new and conventional set of symbols with verbal definitions. A higher percentage of correct matches was made for the new symbols than for the conventional symbols (91 vs. 47 percent).

Hemingway, Kubala, and Chastain (1979) also concluded that pictorial symbols are preferred over geometric and traditional tactical symbols. Civilians were asked to rank four types of symbols by preference -- American military, Soviet military, geometric, and pictorial -- for 24 military objects (such as an infantry unit and a surface-to-air missile emplacement). Pictorial symbols (the most frequent response) were preferred for 11 objects. The authors concluded, however, that this task was only remotely associated to tasks performed by operators when viewing symbols on CRT displays. In a subsequent study, Hemingway and Kubala (1979) found that a set of geometric symbols was interpreted more rapidly, but not more accurately, than a standard set of conventional tactical symbols on a paper map. However, color was used as a redundant coding technique for the geometric symbols. For this reason, the relationship between geometric shape and interpretation time (or identification time) is not clear.

Bersh, Moses, and Maisano (1979) asked military personnel to rank the extent to which simple geometric forms (such as diamonds and circles) represented verbal definitions for military objects. Other participants performed the converse task of ranking the extent to which the verbal definitions represented the symbols. The authors concluded that there is often a "natural" association between conventional military symbols and their verbal definitions since one-half of the matches obtained in the rankings tasks were in the "high association" and "moderate association" categories. The natural associations typically represented numerosity and unit strength, such as a company- or division-level military unit. The authors concluded that these symbols could be easily learned and interpreted.

Ciccone, Samet, and Channon (1979) attempted to identify military symbols that are compatible with "current and emergent tactical doctrine." The authors developed tactical scenarios and then used an analytical approach in developing a taxonomy described as consisting of "basic information-processing behaviors which include symbol discrimination, display search, and symbol learnability." Four types of symbol sets are presented as design candidates from the analysis: modified conventional symbology, tactical capability symbology, combat power symbology, and iconic symbology. Examples of each symbol type are shown in Figure 9.

A Modified Conventional Symbol (Armor -- 100% Strength)



A Tactical Capability Symbol (Armor Unit -- High Threat)

A Combat Power Symbol (Armor)

An Iconic Symbol (Armor)

Figure 9. Examples of four types of symbols for representing tactical doctrine (Ciccone, Samet, and Channon, 1979).

There are two problems in adapting this study to the development of symbols for the CGTD. First, the logical progression from the analysis and taxonomy to recommended symbol design is unclear. Second, the resulting symbology usually exceeds the resolution capabilities of a pixel matrix unless the symbols occupy a very large area on the display.

Geiselman, Landee, and Christen (1979) developed an "index of perceptual discrimination" to select symbols for use in existing symbol sets and graphic displays. Civilian participants were instructed to rate the degree of similarity between military symbols on a scale of one to five. Based on regression analysis of the resulting intersymbol similarity matrix, the authors concluded that symbol similarity is determined by the number of shared versus unique "configural attributes" (undefined, except by example) rather than the number of "primitive attributes" (such as arcs or number of lines). The symbols with the highest discriminability indexes generally produced the shortest response times in a subsequent visual search task.

Sidorsky, Gellman, and Moses (1979) describe current efforts by the U.S. Army to develop tactical symbols. The authors concluded that symbol development will involve modifying and expanding the symbol sets contained in FM 21-30 and FM 21-31 instead of developing an entirely new symbol set. This conclusion is based on two considerations. First, the cost of developing and implementing an entirely new symbol set would outweigh its benefits. Presumably, maps would need to be modified and personnel retrained. Second, the new symbology might not be compatible with NATO symbology. Since the procedures for changing symbology are not clearly defined in Army doctrine, this situation is likely to last into the foreseeable future. However, the authors describe research questions that must be addressed in the development of new symbology. In general, these issues focus on user requirements for map information, methods of presenting symbols to enhance display clarity, and development of symbols that convey information required for command functions.

In summary, past research efforts do not provide firm guidelines that are directly applicable to the design of pixel matrix symbols, but several general principles emerged:

- Map symbols can represent topographic features and military objects in five ways: pictorial likeness, part of the whole, verbal definition, geometric representation, or related object.
- A symbol that represents a pictorial likeness of the object is more likely to be correctly identified than other representations.
- Numerosity is an acceptable method for representing unit strength.
- Whenever possible, symbols for the CGTD should be based on current symbology to minimize retraining requirements and maximize compatibility with other mapping techniques.

Most experimental methods in the studies that were reviewed involved some form of symbol-to-symbol or symbol-to-meaning matching task. These tasks were appropriate both to the examination of symbol similarity and to the study of association strength between symbols and verbal meanings. Matching tasks have the additional advantages of: ease of testing many participants simultaneously, simplicity of performing the required tasks, and capability of obtaining large amounts of quantitative data in a time- and cost-effective manner.

No studies were found, however, that assessed transfer of training from current symbols to candidate symbols. Transfer of training is a critical concern in the current effort since the proposed symbols for the CGTD should require minimum retraining of Army aviators.

SYMBOL DEVELOPMENT FOR THE CGTD

A committee of four members of the Anacapa staff developed a preliminary set of 69 symbols for the CGTD. These symbols represented topographic and tactical items that were determined to be particularly important through a survey of Army aviators (Rogers, 1982). The symbol development committee initially worked individually to create candidate symbols representing the required topographic and tactical features. Subsequently, a series of free-wheeling working sessions were conducted to identify the virtues and shortcomings of the preliminary sets of candidate symbols. Finally, committee members participated in joint symbol development conferences, consisting of creative and analytical activities, until converging upon the set of candidate symbols for use in the evaluation

studies. The following criteria, based on the literature review and the constraints of a CGTD, were used to develop the symbols.

Symbol Size

Symbols were designed to fit into an 8 x 8 pixel matrix. Symbols of this size are large enough to be legible on anticipated display devices (Rogers, Gutmann, and Ralstin, 1982), but not so large as to clutter the map and obscure other features. Also, an 8 x 8 pixel-matrix allows for a potentially enormous number of different symbols.[1]

Content

In order to maximize transfer of training, the candidate symbols were designed to resemble the current symbols whenever possible. In other instances, the proposed symbols represent pictorial likenesses of the object (plan or frontal view), verbal definitions, parts of the whole object, geometric forms, or related objects. Examples of candidate symbols for the CGTD that meet one or more of these criteria are shown in Figure 10.

Distinctiveness

Symbols were designed to be easily distinguishable from each other. Differences of only a few pixels were avoided to reduce symbol confusion.

Similarity

The same basic structure was used with appropriate modifications to facilitate recognition and classification of related symbols. This procedure corresponds to present military practice for symbol design. An example of related symbols is shown in Figure 11.

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[1]The number of possible symbols (although many would be extremely similar) is 2^{64} or over 18 quintillion. Consider, for example, that if a computer were programmed to generate every pattern for an 8 x 8 matrix, it would take nearly six billion years to print the symbols at a rate of 100 per second; and if each symbol were contained in a .25-inch square and then laid end-to-end, the string would stretch to the sun and back about 40,000 times.

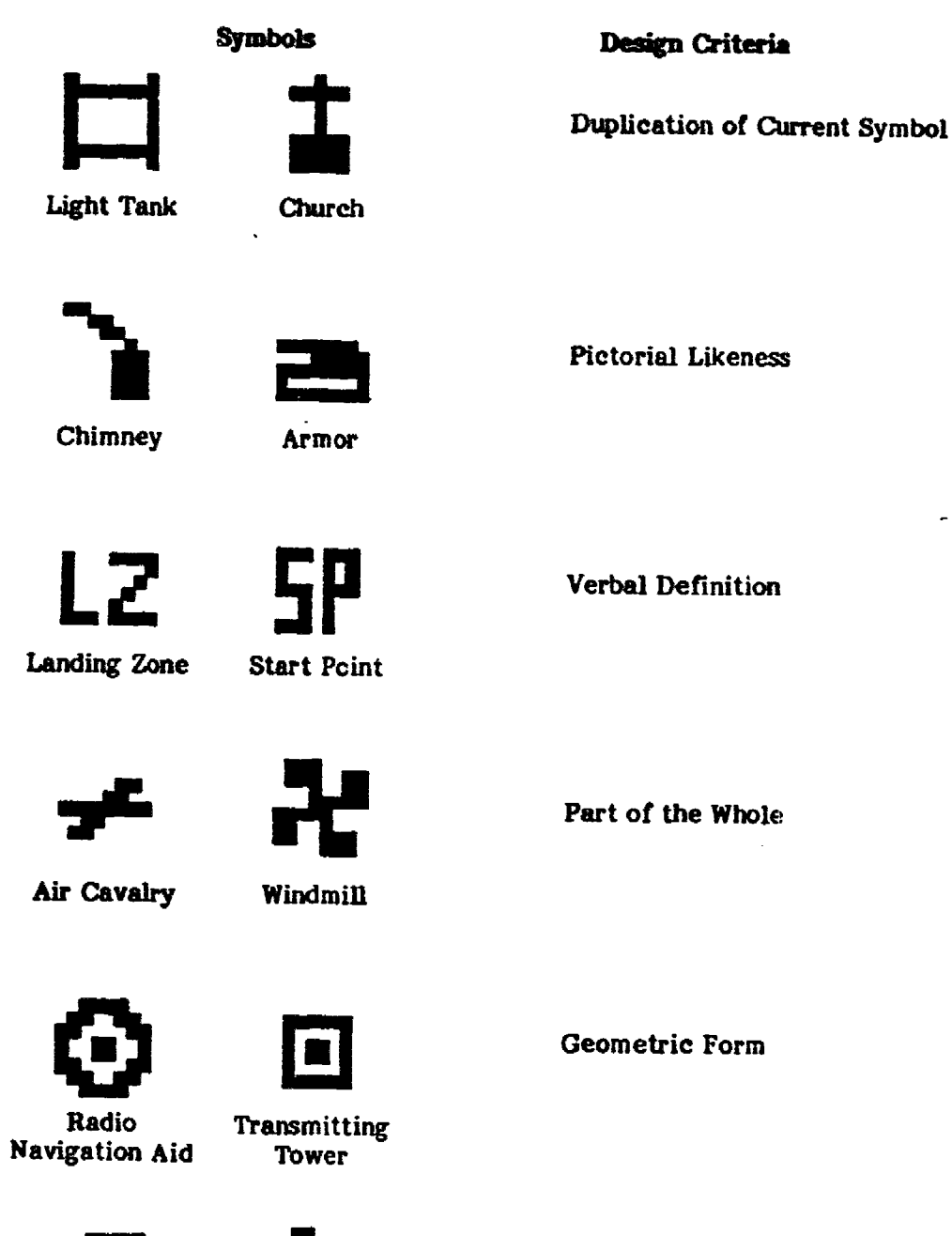

Figure 10. Examples of candidate symbols for the CGTD and applicable design criteria.

Air Defense Gun (Light) | Air Defense Gun (Medium) | Air Defense Missile (Light) | Air Defense Missile (Medium)

Figure 11. Example of related symbols for the CGTD and their similarity in appearance.

Numerosity

Symbols for military units (such as armor or air cavalry) were designed to fit a 5 x 8 pixel matrix. The remaining area of pixels was reserved for designating unit size, such as a company- or battalion-level armor unit. Pattern and numerosity were used to distinguish between symbols for unit size, as shown in Figure 12.

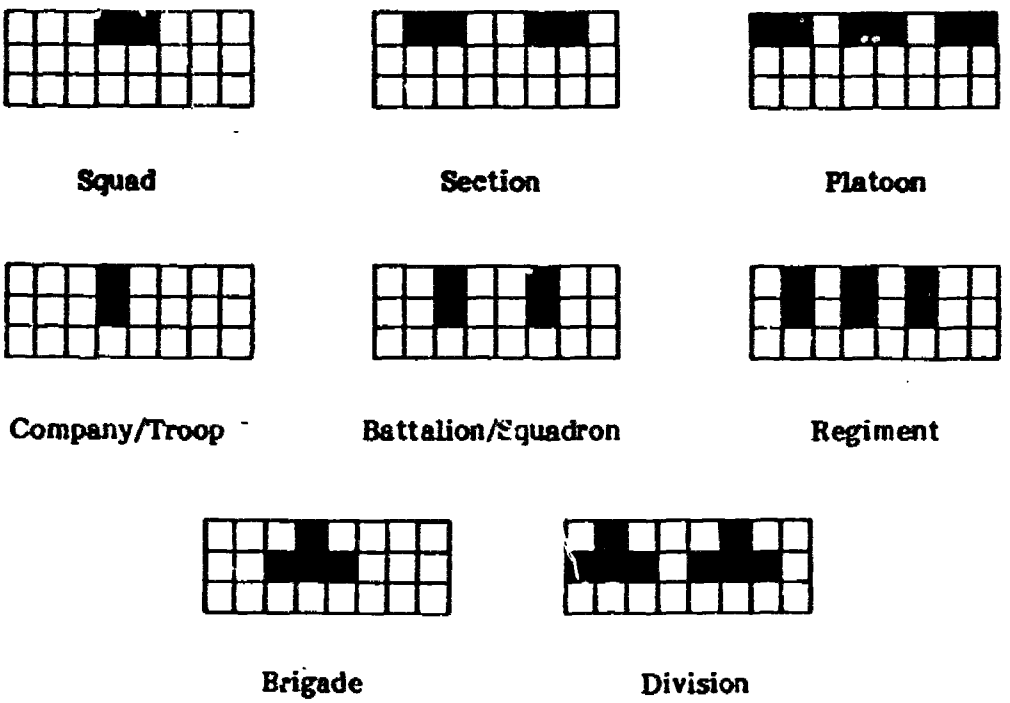

Figure 12. Top portions of the 8 x 8 pixel matrix for designating unit size.

In summary, the candidate symbols for the CGTD were developed to satisfy specific design criteria. The candidate symbols are contained in the survey booklets in Appendices I and IV.

EVALUATION OF CANDIDATE SYMBOL EFFECTIVENESS

The evaluation of the effectiveness of candidate symbols for the CGTD is described in the subsequent sections of this report. A brief overview is provided here to indicate the overall structure and philosophy of this evaluation. Symbol effectiveness is defined by the following three criteria:

- The extent of transfer of training from the symbol currently used on paper maps to the candidate symbol,
- The likelihood that a candidate symbol will be confused with other symbols in the candidate set, and
- The extent to which a candidate symbol is associated with its verbal definition.

The evaluation of the proposed symbols was conducted by the use of three matching tasks. In the first task, the participants indicated whether any similarity existed between symbols in the candidate set and the current set. Because the participants could view both symbol sets in their entirety, the matching task was the analog of a transfer-of-training study in which the participants had "perfect recall." Similarity between corresponding symbols in the two sets indicated positive transfer of training while similarity between non-corresponding symbols indicated negative transfer of training.

In the second matching task, the participants indicated whether any similarity existed among symbols within the candidate set. Similarity between symbols indicated potential for confusion.

In the third task, participants selected the verbal definition that best represented each symbol in the candidate set. Association values were then computed for the pairings to indicate how well each symbol conveyed its verbal meaning.

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SECTION III.
STUDY ONE: TRANSFER OF TRAINING AND SYMBOL CONFUSION

This study was conducted to examine the perceived similarity between candidate map symbols for the CGTD and the map symbols in current use. The amount of similarity provides a measure of the transfer of training that would result if the new candidate symbols were implemented. In addition, the study addressed the similarity among the candidate symbols to identify potential sources of confusion.

METHOD

Survey Tasks

An example of the survey booklet is provided in Appendix 1. This booklet illustrates the set of current topographic and tactical symbols and the set of candidate symbols. The sets are provided in random order for use in two self-administered matching tasks. In the first task, survey participants were asked to identify cases in which current symbols were similar to the candidate symbols. Each candidate symbol was compared with each current symbol, employing the following definition of symbol similarity:

> **Symbols are similar if their shapes bear a sufficient resemblance so that they might be substituted for each other, either on purpose or by accident.**

The current set consisted of symbols with meanings that correspond to the meanings of the candidate symbols. In some instances, current symbols were not available since the candidate symbols were not based on past symbology. For example, current symbols were not available for grain elevator, power station, and offshore platform.

Survey participants were instructed to write "none" on the answer sheet if none of the current symbols resembled a candidate symbol. If one or more current symbols did resemble a candidate symbol, participants were instructed to write the appropriate identification codes on the answer sheet.

In Task Two, survey participants were asked to compare the candidate symbols with each other to determine their similarity, using the definition presented above. Evidence of symbol similarity would indicate a potential for symbol confusion within the candidate set. Participants wrote their responses on an answer sheet, as in Task One.

Survey Participants

The survey participants were 16 unpaid volunteers from the 1st Battalion, 144th Field Artillery Division of the California National Guard in Santa Barbara, California. The battalion training officer (S3) selected survey participants who had above-average experience in reading and interpreting military maps. The participants included five commissioned officers, nine noncommissioned officers, two specialists, and one cadet.

RESULTS

The survey data were tabulated and included in Appendices 2 and 3. Since Tasks One and Two were designed to study different effects, the results are described separately below.

Task One: Transfer of Training

Transfer of training from a current symbol to a candidate symbol could be positive, negative, or zero. For example, positive transfer occurred when a candidate symbol was similar to the corresponding current symbol. Negative transfer occurred when a candidate symbol was similar to a current symbol with a completely different verbal meaning. Zero transfer occurred when a candidate symbol did not resemble any symbol in the current set. The relationship between these three categories is shown on the following scale:

High Negative Transfer	Zero Transfer	High Positive Transfer
-1.00	0	+1.00

The numeric values on the scale, representing a "transfer of training quotient," are computed using the following formula:

$$Q_{tran} = \frac{\text{Most frequent response (excluding "none similar" responses)}}{\text{Total number of responses}} \times \text{Direction of transfer}$$

Direction of transfer is positive (+1) when the most frequent response is the current symbol with the same meaning, and negative (-1) when the most frequent response is a current symbol with a different meaning. Application of the formula to survey data is described below.

Computations Yielding Positive Transfer

The distribution of responses for the candidate symbol "release point," is provided in Table 1.

TABLE 1
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, RELEASE POINT (TRANSFER OF TRAINING STUDY).

Current Symbol	Number of Responses
Release point	16
Passage point	1
Total	17

The transfer of training quotient was computed by substituting the appropriate values into the formula described above:

$$Q_{tran} = \frac{16}{17} \times (+1)$$
$$= +.94$$

The quotient indicates high positive transfer from the current symbol to the candidate symbol for release point.

Computations Yielding Negative Transfer

The distribution of responses for the candidate symbol "mechanized infantry unit" is provided in Table 2.

TABLE 2
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, MECHANIZED INFANTRY UNIT (TRANSFER OF TRAINING STUDY)

Current Symbol	Number of Responses
Medical Unit	8
Armor Unit	1
Infantry Unit	1
Pagoda	1
"None similar"	7
Total	18

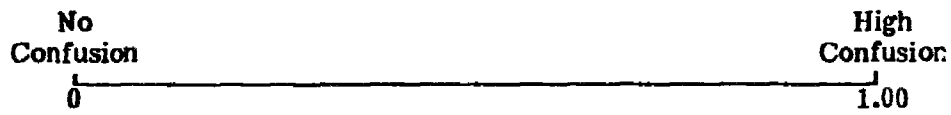
The direction of transfer is negative since an unintended current symbol (medical unit) was the most frequent response. The transfer of training quotient was computed by substituting the appropriate values in Table 2 into the formula provided above:

$$Q_{tran} = \frac{8}{18} \times (-1)$$
$$= -.44$$

The transfer of training quotients for the proposed topographic and military symbols are provided in Tables 3 and 4. The symbol descriptions are presented in descending order from high positive transfer (such as cemetery and pick-up point) to high negative transfer (such as playing field and armored cavalry unit). Candidate symbols without current analogs (marked by asterisks in Tables 3 and 4) had at least low negative transfer. The transfer of training quotients could not exceed zero since the intended response was "none similar." A few discrepant responses could account for the slightly negative values for some candidate symbols.

Task Two: Symbol Confusion

The potential for confusion between symbols within the candidate set could range from no confusion to high confusion. These possibilities and all intermediate possibilities can be contained on the following scale:



Numeric values for the scale, representing "confusion quotients," are computed using the following formula:

$$Q_{conf} = 1 - \frac{\text{Number of "none similar" responses}}{\text{Total number of responses}}$$

TABLE 3
TRANSFER OF TRAINING QUOTIENTS FOR CANDIDATE TOPOGRAPHIC SYMBOLS

Q_{trans}	Survey Booklet Code/Candidate Topographic Symbol
1.00	A57. Cemetery
.88	A61. Church
.88	A68. Mine
.88	A42. School
.81	A64. Railroad station
.44	A62. Radionavigation aid
.42	A29. Airport
.29	A22. Bridge
.25	A20. Vertical obstruction
.19	A41. Falls or rapids
-.06	A48. Cooling tower*
-.06	A12. Grain elevator*
-.06	A43. Power station*
-.06	A19. Windmill
-.12	A18. Tall building*
-.13	A15. Air control tower*
-.13	A51. Dam
-.13	A54. Radar reflector*
-.17	A24. Outdoor theater*
-.18	A38. Lighthouse
-.19	A36. Lookout tower*
-.19	A44. Silo*
-.19	A47. Stadium*
-.20	A1. Chimney or smokestack*
-.25	A7. Monument *
-.25	A3. Storage tank
-.27	A59. Steeple or spire*
-.33	A4. Offshore platform*
-.35	A55. Water tower*
-.47	A40. Playing field*
-.94	A52. Transmitting tower

*Candidate symbol without current analog.

TABLE 4
TRANSFER OF TRAINING QUOTIENTS FOR CANDIDATE MILITARY SYMBOLS

Q_{trans}	Survey Booklet Code/Candidate Military Symbol	
1.00	A2.	Pick-up zone
1.00	A11.	Start point
1.00	A35.	Target (standard symbol)
.94	A32.	Heavy tank
.94	A50.	Landing zone
.94	A6.	Release point
.94	A46.	Unconfirmed
.88	A26.	Holding area
.80	A5.	Light tank
.75	A53.	Attack position
.71	A67.	Air defense gun (medium)
.67	A31.	Air defense gun (light)
.67	A27.	Air passage point
.65	A60.	Medium tank
.61	A16.	Missile in air defense role (light)
.59	A10.	Communications checkpoint
.56	A63.	Missile in air defense role (medium)
.41	A34.	Air control point
.41	A14.	Objective
.41	A25.	Armor unit (nonstandard symbol)
.22	A66.	Observation post
.19	A56.	FARRP (forward area rearm and resupply point)
.18	A9.	Artillery unit
.06	A8.	Armor unit (standard symbol)
.06	A13.	Rally point
-.06	A21.	Pick-up point
-.06	A39.	Target (nonstandard symbol)
-.07	A69.	Infantry unit
-.11	A17.	Air cavalry unit
-.11	A23.	Aviation unit
-.12	A30.	Air defense artillery unit
-.19	A49.	Battle position
-.19	A58.	Mechanized infantry unit (black on white)
-.25	A33.	Attack aviation unit
-.25	A37.	Cavalry unit
-.44	A28.	Mechanized infantry unit (white on black)
-.59	A65.	Armored cavalry unit
-.69	A45.	Checkpoint

The formula is applied to the distribution of responses for the candidate symbol "grain elevator," in Table 5.

TABLE 5
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, GRAIN ELEVATOR (SYMBOL CONFUSION STUDY)

Candidate Symbol	Number of Responses
Target	2
Cavalry unit	1
"None similar"	8
Total	11

By substituting the appropriate values into the formula described above, the confusion quotient is:

$$Q_{conf} = 1 - \frac{8}{11}$$
$$= .27$$

The quotient indicates relatively low confusion between the symbol for grain elevator and other symbols in the candidate set.

On the other hand, consider the response distribution listed in Table 6 for the candidate symbol for "aviation unit."

TABLE 6
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, AVIATION UNIT (SYMBOL CONFUSION STUDY)

Candidate Symbol	Number of Responses
Artillery unit	6
Attack aviation unit	3
Cavalry unit	1
Transmitting tower	1
"None similar"	1
Total	12

The confusion quotient is .92 (1 minus the quotient of 1 divided by 12), indicating a high potential for confusion between the symbol for aviation unit and other symbols in the candidate set.

Transfer of training quotients for the candidate topographic and military symbols are listed in Tables 8 and 9. The symbol descriptions are presented in ascending order from low confusion (such as outdoor theater and holding area) to high confusion (such as water tower and infantry unit). Symbols marked by asterisks have no analog in the current symbol set.

TABLE 7
CONFUSION QUOTIENTS FOR CANDIDATE TOPOGRAPHIC SYMBOLS

Q_{conf}	Survey Booklet Code/Candidate Topographic Symbol	
0	A41.	Falls or rapids
.09	A24.	Outdoor theater
.09	A64.	Railroad station
.09	A44.	Silo*
.09	A59.	Steeple or spire*
.09	A18.	Tall building*
.18	A54.	Radar reflector*
.25	A4.	Offshore platform*
.25	A19.	Windmill
.27	A15.	Air control tower
.27	A51.	Dam
.27	A12.	Grain elevator*
.27	A38.	Lighthouse
.27	A68.	Mine
.27	A40.	Playing field*
.27	A43.	Power station*
.27	A42.	School
.33	A48.	Cooling tower*
.36	A1.	Chimney or smokestack*
.36	A36.	Lookout tower*
.36	A47.	Stadium*
.40	A29.	Airport
.40	A57.	Cemetery
.45	A20.	Vertical obstruction
.46	A62.	Radionavigation aid
.54	A7.	Monument*
.55	A61.	Church
.67	A52.	Transmitting tower
.73	A22.	Bridge
.92	A55.	Water tower*
1.00	A3.	Storage tank

*Candidate symbol without current analog

TABLE 8
CONFUSION QUOTIENTS FOR CANDIDATE SYMBOLS

Q_{Conf}	Survey Booklet Code/Candidate Military Symbol	
0	A25.	Armor unit (nonstandard symbol)
.09	A26.	Holding area
.09	A2.	Pick-up zone
.09	A46.	Unconfirmed
.18	A50.	Landing zone
.18	A14.	Objective
.22	A21.	Pick-up point
.25	A10.	Communications checkpoint
.25	A35.	Target (standard symbol)
.27	A53.	Attack point
.27	A56.	FARRP (forward area rearm and resupply point)
.33	A6.	Release point
.34	A17.	Air cavalry unit
.36	A13.	Rally point
.38	A27.	Air passage point
.42	A34.	Air control point
.42	A11.	Start point
.50	A65.	Armored cavalry unit
.55	A30.	Air defense artillery unit
.55	A39.	Target (nonstandard version)
.58	A31.	Air defense gun (light)
.58	A45.	Checkpoint
.58	A58.	Mechanized infantry unit (black on white)
.60	A28.	Mechanized infantry unit (white on black)
.60	A66.	Observation post
.62	A60.	Medium tank
.64	A5.	Light tank
.64	A16.	Missile in air defense role (light)
.64	A63.	Missile in air defense role (medium)
.67	A8.	Armor unit (standard symbol)
.67	A32.	Heavy tank
.73	A9.	Artillery unit
.73	A37.	Cavalry unit
.75	A67.	Air defense gun (medium)
.77	A49.	Battle position
.92	A33.	Attack aviation unit
.92	A23.	Aviation unit
1.00	A69.	Infantry unit

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SECTION IV.
STUDY TWO: SYMBOL ASSOCIATION

This study was conducted to determine the amount of association between the candidate map symbols for the CGTD and their verbal definitions. The amount of association provides a measure of how well each symbol conveys its intended meaning. The following subsections describe the survey.

METHOD

Survey Task

An example of the self-administered survey is contained in Appendix 4. Survey participants were asked to match the candidate symbols to verbal definitions. Additional definitions beyond those intended for the symbols were included in the list of definitions to enhance the generalizability of the survey results. The definitions were listed alphabetically to decrease search time. Participants were asked to write "none" or the numeric codes for the desired definitions on the answer sheet. Participants were asked to provide only one response (verbal definition) for each candidate symbol.

Survey Participants

The survey participants were 17 unpaid volunteers from the 1st Battalion, 144th Field Artillery Division of the California National Guard in Santa Barbara, California. The battalion training officer (S3) selected participants who had above-average experience in reading and interpreting military maps. The participants included four commissioned officers, eleven noncommissioned officers, one specialist, and one cadet. Participants in Study One did not participate in Study Two to avoid undesired effects of experience with the candidate symbols.

RESULTS

The survey data were tabulated and included in Appendix 5. Association quotients were computed to determine the amount of association between the candidate symbols and their intended verbal definitions. The association quotients

could be positive, negative, or zero to indicate the type of relationship between symbols and definitions. For example, a positive association quotient indicates that an intended definition is associated with a symbol. A negative association quotient indicates that an unintended definition is associated with a symbol. A zero association quotient indicates that no definition is consistently associated with a symbol. The relationship between the three values of association quotients is shown on the following scale.

High Association Between Symbol and Unintended Meaning	No Association	High Association Between Symbol and Intended Meaning
-1.00	0	+1.00

The numeric values for association quotients are computed using the following formula:

$$Q_{assn} = \frac{\text{Most frequent definition (excluding "none" responses)}}{\text{Total number of responses}} \times \text{Direction of association}$$

The direction of association is positive (+1) when the most frequent responses is the intended verbal definition and is negative (-1) when the most frequent response is an unintended definition. Application of the formula to survey data is described below.

Computations Yielding Positive Association Quotients

The distribution of responses for the candidate symbol, "chimney or smoke-stack," is provided in Table 9.

TABLE 9
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, CHIMNEY OR SMOKESTACK (SYMBOL ASSOCIATION STUDY)

Verbal Definition	Number of Responses
Chimney or smokestack	15
Cooling tower	1
Power station	1
Total	17

The association quotient was computed by substituting the values in Table 9 into the formula described above.

$$Q_{assn} = \frac{16}{17} \times (+1)$$
$$= +.94$$

The quotient indicates high association between the symbol and its intended definition.

Computations Yielding Negative Association Quotients

The distribution of responses for the candidate symbol, "storage tank," is shown in Table 10.

TABLE 10
DISTRIBUTION OF RESPONSES FOR THE CANDIDATE SYMBOL, STORAGE TANK (SYMBOL ASSOCIATION STUDY)

Verbal Definition	Number of Responses
Water (Combat Service Support Activity)	9
FARRP (Forward Area Rearm and Resupply Point)	2
Water Tower	2
Dam	1
Repair and Maintenance Unit	1
Storage Tank	1
None	1
Total	17

The association quotient was computed by substituting the values from Table 10 into the formula:

$$Q_{assn} = \frac{9}{17} \times (-1)$$
$$= -.53$$

The quotient indicates an association between the symbol for storage tank and an unintended verbal definition, "water" (combat service support activity).

Association quotients for the proposed topographic and military symbols are provided in Tables 11 and 12. The symbols are presented in rank order from high association with intended definitions (such as water tower and checkpoint) to high association with unintended definitions (such as vertical obstruction and pick-up zone). Candidate symbols without analogs in the current set are marked by asterisks.

TABLE 11
ASSOCIATION QUOTIENTS FOR CANDIDATE TOPOGRAPHIC SYMBOLS

Q_{comp}	Survey Booklet Code/Candidate Topographic Symbol
.88	A1. Chimney or smokestack*
.88	A55. Water tower*
.83	A29. Airport
.82	A61. Church
.82	A41. Falls or rapids
.82	A64. Railroad station
.76	A57. Cemetery
.59	A68. Mine
.59	A42. School
.59	A18. Tall building*
.41	A19. Windmill
.35	A22. Bridge
.35	A51. Dam
.35	A12. Grain elevator*
.33	A47. Stadium*
.12	A4. Offshore platform*
.06	A24. Outdoor theater*
-.18	A40. Playing field*
-.18	A43. Power station*
-.18	A62. Radionavigation aid
-.18	A44 Silo*
-.20	A52. Transmitting tower
-.22	A38. Lighthouse
-.24	A48. Cooling tower*
-.24	A7. Monument*
-.24	A54. Radar reflector*
-.24	A59. Steeple or spire*
-.25	A36. Lookout tower*
-.29	A20. Vertical construction
-.53	A3. Storage tank

*Candidate symbol without current analog.

TABLE 12
ASSOCIATION QUOTIENTS FOR CANDIDATE MILITARY SYMBOLS

Q_{comp}	Survey Booklet Code/Candidate Military Symbol
1.00	A45. Checkpoint
1.00	A10. Communications checkpoint
1.00	A50. Landing zone
1.00	A66. Observation post
1.00	A2. Pick-up zone
1.00	A11. Start point
.94	A27. Pick-up point
.94	A46. Unconfirmed
.82	A49. Battle position
.65	A35. Target (standard symbol)
.53	A6. Release point
.47	A14. Objective
.41	A26. Holding area
.35	A34. Air control point
.25	A63. Missile in air defense role (medium)
.24	A65. Armored cavalry unit
.24	A5. Light tank
.24	A16. Missile in air defense role (light)
.22	A53. Attack position
.21	A31. Gun in air defense role (light)
.18	A32. Heavy tank
.18	A60. Medium tank
.12	A37. Cavalry unit
.06	A69. Infantry unit
-.12	A9. Artillery unit
-.12	A23. Aviation unit
-.12	A28. Mechanized infantry unit (white on black)
-.13	A56. FARRP (forward area rearm and resupply point)
-.17	A67. Gun in air defense role (medium)
-.18	A30. Air defense artillery unit
-.18	A8. Armor unit (Standard symbol)
-.18	A33. Attack aviation unit
-.18	A39. Target (nonstandard symbol)
-.19	A13. Rally point
-.24	A17. Air cavalry unit
-.29	A58. Mechanized Infantry unit (black on white)
-.35	A15. Airfield tower
-.47	A25. Armor unit (nonstandard version)
-.47	A21. Pick-up point

SECTION V
DISCUSSION

It is interesting to note that the quotients for transfer of training, association value, and potential confusion of candidate map symbols spanned the entire range of numeric values. For example, the transfer of training quotients for topographic symbols represented positive, negative, and near-zero values. This finding suggests that the survey method provided sufficient precision for determining the relative effectiveness of the map symbols.

The participants reported very little difficulty in completing the survey tasks. A review of the answer sheets indicated that the participants performed the tasks correctly. However, a few participants mentioned the excessive length of the survey. Although the participants were required to make as many as 5300 comparisons (in the transfer-of-training task), no time limits were imposed on this activity, and examination of the answer sheets does not suggest that tedium or fatigue adversely affected the data collection process.

The completion of the survey tasks provided data to meet three project objectives. In review, these objectives were to: determine the degree of transfer of training from the current set of symbols used on paper maps to the candidate set for the CGTD, determine the potential for confusion among symbols within the candidate set, and determine the levels of association between the candidate symbols and their verbal definitions. The following sections discuss the extent to which each of these objectives was met by the studies.

TRANSFER OF TRAINING

The results of the transfer of training study provided relatively clear-cut distinctions among classes of symbols for the CGTD. These classes included military unit symbols, symbols that replicate current symbol design, symbols that do not replicate current symbol design, and symbols without current analogs.

Military unit symbols (such as representations of aviation and air defense units) had low or negative transfer of training from the conventional symbols used on paper maps. In most instances, the design of the unit symbols was based on

current symbol design. However, there were two problems with this approach. First, the identifying element within the symbol (such as a propeller or radar dome) could not be portrayed with fidelity because of the "stair-step" effect inherent in portraying curved lines in a pixel matrix. Second, the border surrounding the identifying element usually could not be portrayed because of space limitations imposed by an 8 x 8 matrix. Interestingly, a simplified iconic representation of an armor unit (a tank) had a higher transfer of training quotient than the attempt to replicate the current symbol (.41 vs. .06). This finding provides some support for using iconic symbols on tactical maps, as recommended by Ciccone, Samet, and Channon (1979).

Other military symbols that replicated current symbol design generally had moderate-to-high transfer of training from the intended current symbols. These symbols include standard abbreviations (such as those for pick-up zone and start point) and distinct geometric shapes (such as tanks and air defense weapons). High positive transfer was expected since the participants were experienced map users and very familiar with the current symbol set. Similarly, topographic symbols replicating current symbol design had moderate-to-high positive transfer. These symbols include the commonly depicted representations of cemetery, mine, and school.

Other topographic symbols, however, did not replicate current symbol design because of limitations imposed by a pixel matrix format. In every instance, these symbols had low or negative transfer of training. Examples include symbols for lighthouse, windmill, and dam.

Some candidate topographic symbols did not have current analogs because the features that they represent are not specifically depicted on paper maps. These features include a grain elevator, a smokestack, and an offshore platform. Because of the method for computing the transfer of training quotients, symbols without current analogs had quotients that could not exceed zero. In many instances, these symbols had slight negative transfer because of a few discrepant responses by the survey participants. However, in only three cases did the transfer of training quotient exceed -.30 (on a scale of + 1.00 to -1.00) indicating that the

symbols were generally free of strong association with unintended current symbols. The importance of this finding is that training of aviators to use a CGTD might be reduced because current symbols would not need to be "unlearned" before the completely new symbols are learned.

SYMBOL CONFUSION

The results of the symbol confusion study also provided fairly clear-cut distinctions among classes of symbols for the CGTD. These classes included interrelated military symbols, alphanumeric combinations, military unit symbols, and the entire set of topographic symbols.

Interrelated military symbols (such as classes of tanks and air defense weapons) were judged by survey participants to be similar in appearance. Consequently, related symbols generally had moderate-to-high confusion quotients. This finding was expected because current cartographic practice (U.S. Army 1961 and 1970) is to develop similar symbols for closely related objects to enhance identification and classification.

Military symbols consisting of two-letter abbreviations generally had low confusion quotients. This finding is supported by a review of the experimental literature: McCallum and Rogers (1982), for example, noted that a virtually unlimited number of alphanumeric combinations can be distinguished. Military unit symbols, however, had moderate-to-high confusion quotients.

Topographic symbols, in general, were readily distinguished from each other. Only four symbols had high confusion quotients. Two of the symbols depicted a water tower and storage tank, which were often judged to be similar to each other. In the other two instances, transmitting tower was judged to be similar to radionavigation aid and artillery unit, and bridge was judged to be similar to infantry unit. Once again, problems were encountered in providing sufficient distinction among military unit symbols and their relationship to other candidate symbols for the CGTD.

ASSOCIATION VALUE

The results of the association value study also provided noteworthy distinctions among classes of symbols for the CGTD. These classes included: alphanumeric combinations, symbols that replicate current symbol design, symbols that do not replicate current symbol design, military unit symbols, and symbols without current analogs.

Military symbols consisting of standard abbreviations were generally associated with their intended verbal definitions. Two explanations might account for this finding. First, the use of well chosen abbreviations can suggest the verbal definition. For example, the initials "RP" (the symbol) can be readily associated with "release point" (the definition) in a matching task. Second, and most important, the high association between standard alphanumeric symbols and their intended verbal definitions can be predicted from Osgood's transfer surface model shown on page 9. Examination of the model suggests that the candidate symbols for the CGTD that are extremely similar in appearance to the current symbols for paper maps are likely to have high association with their intended verbal definitions. This condition assumes, of course, that the map user has learned the verbal definitions for the current symbols. Other military symbols that replicate current symbol design, especially distinct geometric shapes such as tanks and target location, were also associated with their intended verbal definitions.

Military unit symbols were often associated with unintended verbal definitions. The large number of different verbal definitions associated with each of these symbols suggests that survey participants were using a "guessing" strategy. For example, seven or more verbal definitions were provided for many of the unit symbols. (This finding was also true for other symbols that had negative association values.)

Topographic symbols replicating current symbol design were generally associated with their intended verbal definitions. This finding can be predicted from the transfer surface model as previously discussed. Conversely, symbols that did not replicate current symbol design generally had low association with their intended verbal definitions or association with unintended definitions. The findings

for symbols without current analogs is less clear: this set of symbols did not show a consistent pattern of association with either intended or unintended verbal definitions. As found by Koponen, Waters, and Orlansky (1952), pictorial symbols (such as chimney and water tower in the current effort) are likely to be strongly associated with their intended verbal definitions since the symbols suggest what is being represented. On the other hand, highly stylized or abstract symbols of cultural features, such as the depiction of a steeple by the letter "S" on a pedestal, had low or negative association value.

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SECTION VI.
SUMMARY AND RECOMMENDATIONS

This section summarizes the results of the survey and provides recommendations for improving the effectiveness of the candidate symbols for the CGTD. As previously discussed, symbol effectiveness refers to transfer of training, potential confusion, and association value of the candidate symbols.

- Military unit symbols had low or negative transfer of training, high potential for confusion, and low association value. These criteria are interrelated, however. For example, symbols that are likely to be confused are also likely to have low association value since map users cannot consistently distinguish among map symbols. The military unit symbols require extensive modification; one possibility is to use iconic symbols such as a side-view of a tank to depict an armor unit.

- Related military symbols (such as air defense weapons) were judged to be similar in appearance. However, transfer of training and association value were generally judged to be moderate-to-high. These symbols should be retained in their present form since similarity can aid in identifying and classifying related objects.

- Standard alphanumeric symbols for tactical information generally met the three evaluation criteria: high transfer of training, low confusion, and high association value. Very few changes are required to this class of symbols.

- Military and topographic symbols replicating current symbol design also generally met the three evaluation criteria. Very few changes are required to this class of symbols.

- Topographic symbols that did not replicate current symbol design, because of limitations imposed by an 8 x 8 pixel matrix format, generally had low transfer of training, very little potential confusion, and zero or slightly negative association value. Because of the variability of the findings for individual symbols, these symbols need to be evaluated on a case-by-case basis to determine which symbols require modification or redesign.

- Topographic symbols without current analogs had zero or slightly negative transfer of training (as expected), very little confusion with other candidate symbols, and either positive or negative association values. Pictorial symbols generally had high positive association values. Modifications to this set could focus on the use of more pictorial symbols to convey verbal definitions to map users without requiring extensive training.

The summary and recommendations provided above describe general classes of symbols. In instances where the findings are less generalizable, evaluation and recommendations should be performed on a case-by-case basis to ensure that each symbol is effective. For example, potential confusion between the candidate symbols for water tower and storage tank could be minimized by changing the shape of the least-effective symbol, depending on the other two evaluation criteria (transfer of training and association value). A framework for evaluation of individual symbols is shown in Table 13.

TABLE 13
MATRIX OF SYMBOL EVALUATION CRITERIA AND QUOTIENT VALUES.

Symbol Evaluation Criteria	Quotient Values		
Transfer of Training	High Positive	None	High Negative
Association Value	High Positive	None	High Negative
Potential Confusion	Low	Moderate	High

Individual symbols that have quotients values for one or more of the criteria represented in the shaded areas are prime candidates for modification or redesign. The process will require a series of iterative steps since meeting one criterion may adversely affect meeting the other criteria. For example, redesign of a symbol to reduce potential confusion could decrease transfer of training if the candidate symbol no longer resembles its current analog. Alternatively, redesign of a symbol to maximize transfer of training could introduce additional confusion into the candidate symbol set if two unrelated symbols now appear similar.

In summary, the studies described in this report -- transfer of training, symbol confusion, and assocation value -- provided useful data for evaluating the relative effectiveness of candidate symbols for a CGTD. The results yielded reasonably clear distinctions among classes of map symbols. Many of the symbols developed during this series of studies may be effectively used without further enhancement. Other symbols may require iterative modifications and evaluations in order to maximize their effectiveness. The guidelines for symbol design and the evaluation methods described in this report provide powerful tools for the development of an effective set of map symbols for the CGTD.

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APPENDIX 1: SURVEY BOOKLET FOR STUDY ONE (TRANSFER OF TRAINING AND SYMBOL CONFUSION TASKS)

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MAP SYMBOL STUDY

I. SYMBOL SIMILARITY

JULY 1982

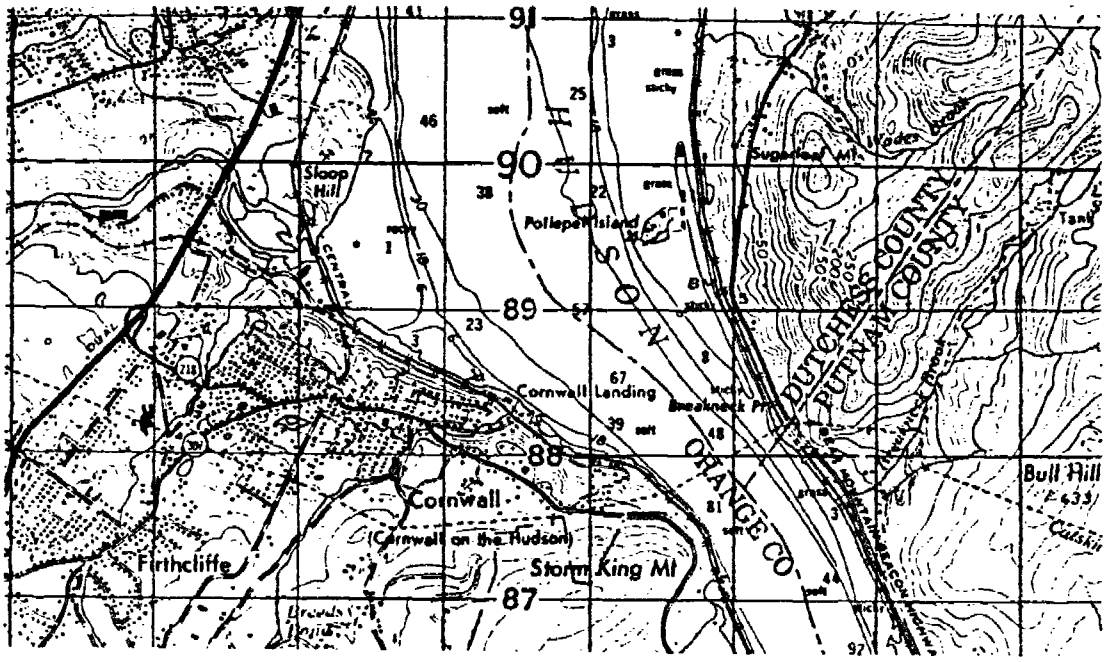
ANACAPA SCIENCES, INC.
P. O. DRAWER Q, SANTA BARBARA, CA 93102
TELEPHONE (805) 966-6157

PURPOSE OF THIS STUDY

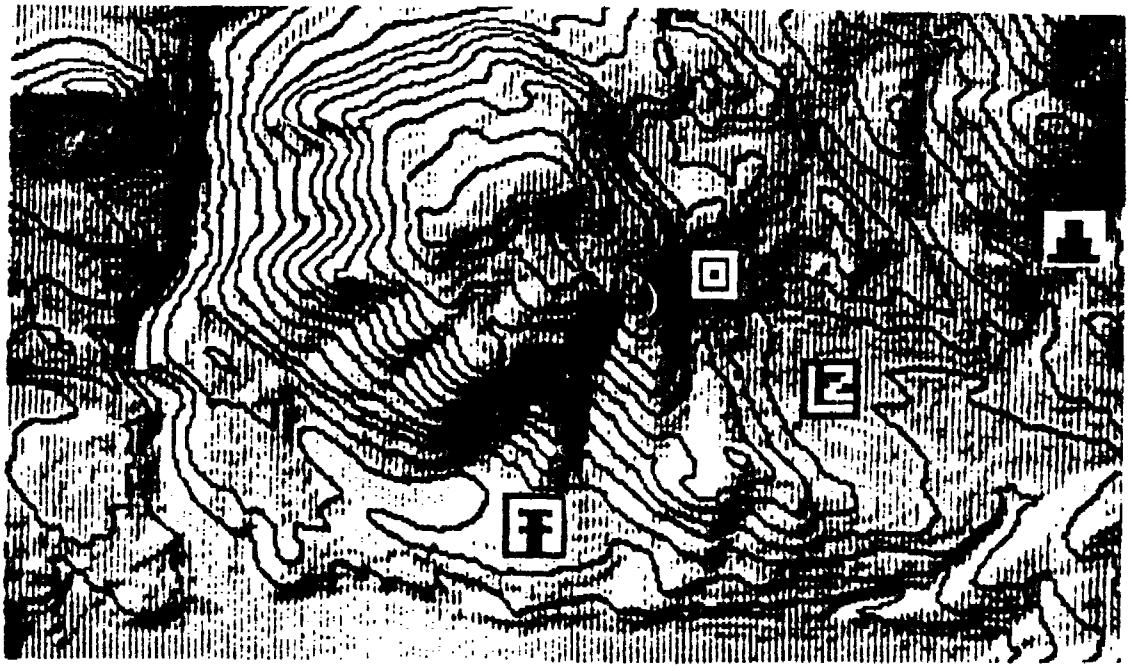
The purpose of this study is to determine the most appropriate shapes for the symbols that will be used in computer-generated maps. As background, the Army Avionics R&D Activity is developing a computer-generated map display system for use in Army helicopters and other tactical vehicles. The system will be small and lightweight, yet it will have extensive capabilities. The computer-generated map will be displayed on a TV screen and will move to provide a continuous update of the vehicle's present position and the surrounding area. The vehicle operator will be able to annotate the map with tactical data before and during the mission. Map features, such as scale, contour interval, relief shading, masked routes and other information, will be selected for display by touching buttons.

The symbology for the computer-generated map display will be chosen to meet the specific requirements of Army aviators and other users rather than copying it from existing paper maps. For example, new types of symbols are needed since electronic displays are not always capable of presenting information in the same detail as paper maps. The difference in detail that is obtainable with paper and computer-generated maps is shown on the adjacent page.

Your participation in this study is important to the development of the map display system. Your help is needed to identify symbols that are potentially useful and symbols that are potentially confusing.



A conventional paper map with current topographic symbols.



A computer-generated map with examples of newly developed symbols.

WHAT YOU SHOULD DO

This study consists of two related but separate tasks. In the first task, you are asked to determine the similarity of electronic display symbols and current military and topographic symbols used on paper maps. In the second task, you are asked to determine the similarities among the electronic display symbols.

Please complete the personal information sheet before you begin the tasks. When you have completed this sheet, read the instructions for Task One on the next page. Both tasks may take some time to complete. If you find that you are tired or your attention has diminished, please stop work on the task and return to it when you are refreshed.

INSTRUCTIONS FOR TASK ONE

1. Look at the first electronic display symbol on the next page. (This symbol is designated A1).

2. Look at each of the current military and topographic symbols, one-by-one, on the page that is adjacent to the electronic display symbols. (The current symbols are designated 1, 2, 3, and so on.)

3. Decide if any of the current symbols are similar to the first electronic display symbol. Use the following definition to judge symbol similarity:

> **Symbol Similarity:**
>
> **Symbols are similar if their shapes bear a sufficient resemblance so that they might be substituted for each other, either on purpose or by accident.**

4. Write the numeric codes for the current symbols that are similar to the electronic display symbol on the appropriate line of the **green** answer sheet. In many instances, you may find that there is no similarity between the electronic display and current symbols. If this is the case, write "none" on the line.

5. Repeat these steps for the second electronic display symbol (A2). Continue performing these steps until you have completed the comparison of every electronic display symbol with every current symbol.

6. When you have completed this task, turn to page seven.

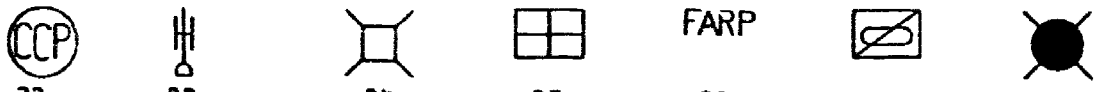
ELECTRONIC DISPLAY SYMBOLS

CURRENT MILITARY AND TOPOGRAPHIC SYMBOLS

1 2 3 4 5 6 7

8 9 10 11 12 13 14

15 16 17 18 19 20 21



22 23 24 25 26 27 28

29 30 31 32 33 34 35

36 37 38 39 40 41 42

43 44 45 46 47 48 49

50 51 52 53 54 55 56

57 58 59 60 61 62 63

64 65 66 67 68 69 70

71 72 73 74 75 76 77

INSTRUCTIONS FOR TASK TWO

1. Look at the first electronic display symbol on the adjacent page. (This symbol is designated A1).

2. Look at each of the other electronic display symbols, one-by-one, on the same page. (These symbols are designated A2 through A69.)

3. Decide if any of the other symbols are similar to the first symbol. Use the following definition, once again, to judge symbol similarity:

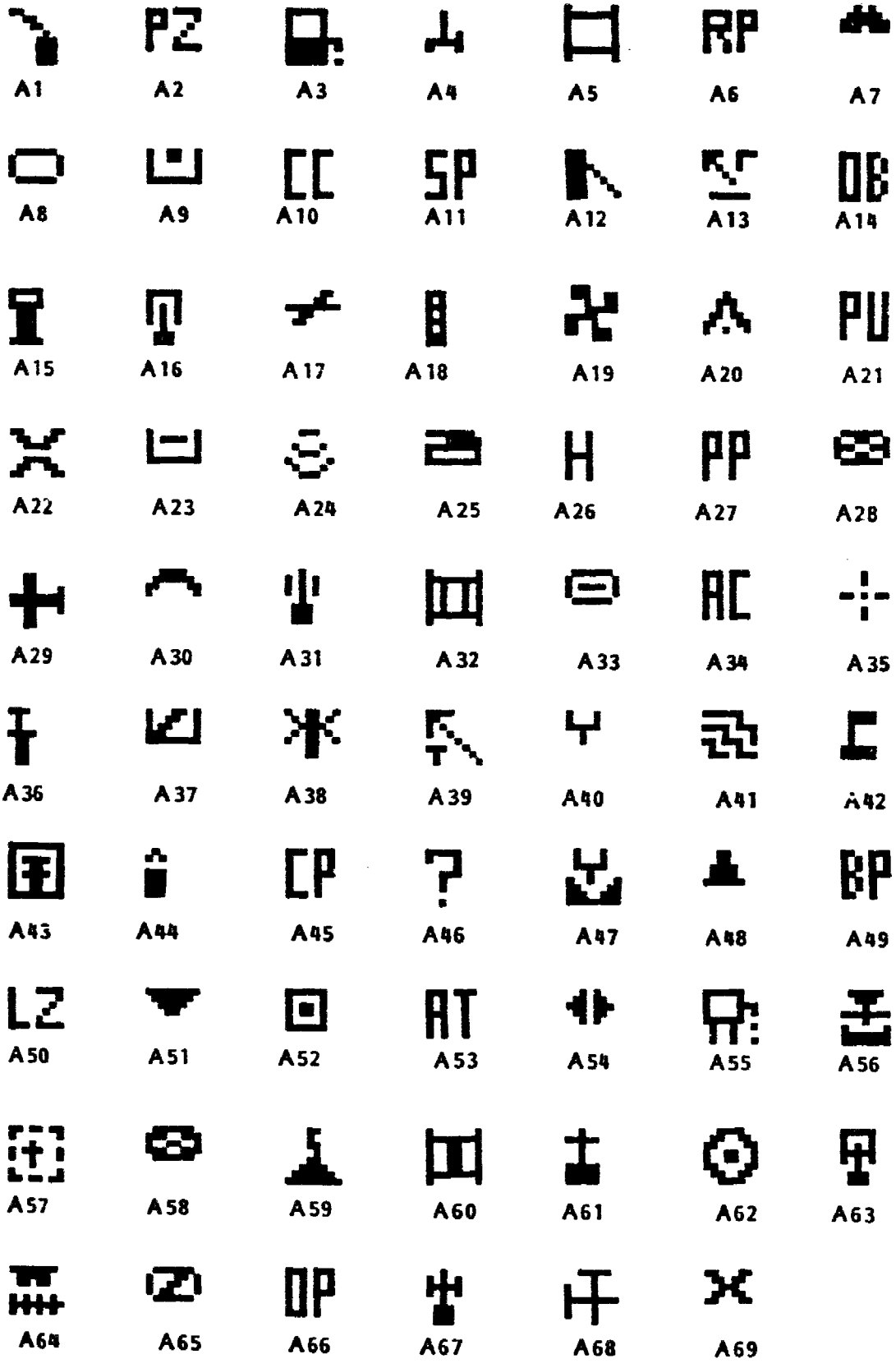
> **Symbol Similarity:**
>
> **Symbols are similar if their shapes bear a sufficient resemblance so that they might be substituted for each other, either on purpose or by accident.**

4. Write the alphanumeric codes for the symbols that are similar to the first symbol on the appropriate line of the yellow answer sheet. In many instances, you may find there is no similarity between a symbol and the other symbols. If this is the case, write "none" on the line.

5. Repeat these steps for the second symbol (A2). Continue performing these steps until you have completed the comparisons for all 69 symbols.

6. When you have completed this task, turn to page nine.

ELECTRONIC DISPLAY SYMBOLS



RETURN OF ANSWER SHEETS

1. If you desire, use the pink sheet that is attached to the answer sheets to make comments about the symbols or the study.

2. Return the booklet and completed answer sheets to the person who gave you the material.

3. That person will return them to Anacapa Sciences.

We would like to thank you for your participation in this study. Your responses will help to determine the best set of symbols for the computer-generated map display system.

APPENDIX 2: RESPONSE DISTRIBUTIONS FOR TRANSFER OF TRAINING TASK

Response distributions for the current symbols judged by survey participants to be similar to the candidate symbols are contained in this section. Responses for intended symbols are noted in bold face type. Single responses for two or more unintended symbols are combined in one category to simplify data presentation.

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A1. CHIMNEY OR SMOKESTACK
None - 12
13. School - 3

A2. PICK-UP ZONE
20. Pick-up zone - 17

A3. STORAGE TANK
None - 9
68. Water supply unit - 4
31. Oil storage tank - 1
Three symbols - 1 each

A4. OFFSHORE PLATFORM
None - 9
68. Water supply unit - 6
Three symbols - 1 each

A5. LIGHT TANK
66. Light tank - 16
7. Medium tank - 3
21. Heavy tank - 1

A6. RELEASE POINT
50. Release point - 15
44. Passage point - 1

A7. MONUMENT
None - 11
37. Engineer unit - 4
31. Oil storage tank - 1

A8. ARMOR UNIT
None - 12
14. Armor unit - 1
Four symbols - 1 each

A9. ARTILLERY UNIT
None - 13
43. Artillery unit - 3
36. Artillery observation post - 1

A10. COMMUNICATIONS CHECKPOINT
22. Communications checkpoint - 10
None - 7

A11. START POINT
69. Start point - 17

A12. GRAIN ELEVATOR
None - 13
Four symbols - 1 each

A13. RALLY POINT
None - 14
Three symbols - 1 each

A14. OBJECTIVE
None - 9
6. Objective - 7
37. Engineer unit - 1

A15. AIR CONTROL TOWER
None - 11
11. FARRP - 2
Three symbols - 1 each

A16. MISSILE IN AIR DEFENSE ROLE (LIGHT)
75. Missile in air defense role (light) - 11
55. Missile in air defense role (medium) - 4
None - 3

A17. AIR CAVALRY UNIT
None - 10
29. Assault crossing - 2
40. Mountain pass - 2
Four symbols - 1 each

A18. BUILDING
None - 12
66. Light tank - 2
Three symbols - 1 each

A19. WINDMILL
None - 9
Nine symbols - 1 each

A20. VERTICAL CONFUSION
None - 9
64. Vertical obstruction - 5
Five symbols - 1 each

A21. PICK-UP POINT
None - 15
Two symbols - 1 each

A22. BRIDGE
3. Bridge - 7
73. Gap - 7
29. Assault crossing - 4
25. Medical unit - 2
None - 2
Two symbols - 1 each

A23. AVIATION UNIT
None - 13
3. Bridge - 2
Three symbols - 1 each

A24. OUTDOOR THEATER
None - 11
72. Radionavigation aid - 3
Four symbols - 1 each

A25. ARMOR UNIT
14. Armor unit - 4
32. Air defense gun (light) - 3
23. Air defense gun (medium) - 2
7. Medium tank - 1

A26. HOLDING AREA
16. Holding area - 15
66. Light tank - 2

A27. AIR PASSAGE POINT
44. Air passage point -12
None - 5
50. Release point - 1

A28. MECHANIZED INFANTRY UNIT (white on black)
25. Medical unit - 8
None - 7
Three symbols - 1 each

A29. AIRPORT
67. Airport - 8
None - 5
2. Aviation unit - 2
Four symbols - 1 each

A30. AIR DEFENSE ARTILLERY UNIT
None - 13
37. Engineer unit - 2
Two symbols - 1 each

A31. AIR DEFENSE GUN (LIGHT)
32 Air defense gun (light) - 14
23. Air defense gun (medium) - 5
Two symbols - 1 each

A32. HEAVY TANK
21. Heavy tank - 17
7. Medium tank - 1

A33. ATTACK AVIATION UNIT
14. Armor unit - 5
74. Repair and maintenance unit - 5
None - 4
2. Aviation unit - 6
19. Attack aviation unit - 1
Three symbols - 1 each

A34. AIR CONTROL POINT
None - 8
56. Air control point - 7
Two symbols - 1 each

A35. TARGET (standard symbol)
76. Target - 17

A36. LOOKOUT TOWER
None - 11
61. Church - 3
Two symbols - 1 each

A37. CAVALRY UNIT
None - 8
17. Cavalry unit - 3
54. Radar station -4
10. Signal unit - 1

A38. LIGHTHOUSE
None - 8
59. Windmill - 3
77. Cemetery - 2
Four symbols - 1 each

A39. TARGET (nonstandard symbol)
None - 13
Three symbols - 1 each

A40. PLAYING FIELD
42. Mosque - 8
None - 6
Three symbols - 1 each

A41. FALLS OR RAPIDS
None - 11
15. Rapids - 2
29. Assault crossing - 1
60. Falls - 1
49. Mountain pass - 1

A42. SCHOOL
13. School - 14
None - 2

A43. POWER STATION
None - 12
Four symbols - 1 each

A44. SILO
None - 12
61. Church - 3
32. Air defense gun (light) - 1

A45. CHECKPOINT
22. Communications checkpoint - 11
None - 2
Three symbols - 1 each

A46. UNCONFIRMED
18. Unconfirmed - 15
None - 1

A47. STADIUM
None - 7
11. FARRP - 3
42. Mosque - 3
47. Transportation unit - 3

A48. COOLING TOWER
None - 15
48. Observation post - 1

A49. BATTLE POSITION
None - 23
50. Release point - 3

A50. LANDING ZONE
44. Landing zone - 15
None - 1

A51. DAM
None - 14
51. Outdoor theater - 2

A52. TRANSMITTING TOWER
43. Artillery unit - 15
None - 1

A53. ATTACK POSITION
4. Attack position - 12
None - 4

A54. RADAR REFLECTOR
None - 11
40. Mountain pass - 2
Three symbols - 1 each

A55. WATER TOWER
None - 6
69. Water supply unit - 6
38. Transmitting tower - 3
46. Checkpoint - 2

A56. FARRP
None - 13
11. FARRP - 3

A57. CEMETERY
77. Cemetery - 16

A58. MECHANIZED INFANTRY UNIT (black on white version)
None - 8
25. Medical unit - 3
57. Infantry unit - 3
8. Mechanized infantry unit - 1
28. Antitank mine - 1

A59. STEEPLE OR SPIRE
None - 11
13. School - 4

A60. MEDIUM TANK
7. Medium tank - 11
21. Heavy tank - 6

A61. CHURCH
61. Church - 14
77. Cemetery - 2

A62. RADIONAVIGATION AID
72. Radionavigation aid - 7
38. Transmitting tower - 4
None - 4
31. Oil storage tank - 1

A63. MISSILE IN AIR DEFENSE ROLE (MEDIUM)
55. Missile in air defense role (medium) - 9
None - 5
Two symbols - 1 each

A64. RAILROAD STATION
65. Railroad station - 13
None - 3

A65. ARMORED CAVALRY UNIT
17. Cavalry unit - 10
10. Signal unit - 4
None - 3

A66. OBSERVATION POST
None - 8
48. Observation post - 4
36. Artillery observation post - 3
64. Vertical obstruction - 2
20. Pick-up zone - 1

A67. AIR DEFENSE GUN (MEDIUM)
23. Air defense gun (medium) - 12
32. Air defense gun (light) - 4
None - 1

A68. MINE
62. Mine - 14
None - 2

A69. INFANTRY UNIT
None - 13
73. Gap - 1

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APPENDIX 3: RESPONSE DISTRIBUTIONS FOR SYMBOL CONFUSION TASK

Response distributions for the candidate symbols judged to be similar to other symbols within the candidate set are contained in this section. Single responses are combined into one category to simplify data presentation.

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A1 CHIMNEY OR SMOKESTACK
None - 7
A44. Silo - 4

A2. PICK-UP ZONE
None - 10
A50. Landing zone - 1

A3. STORAGE TANK
A55. Water tower - 11
A3. Offshore platform - 1

A4. OFFSHORE PLATFORM
None - 9
Three symbols - 1 each

A5. LIGHT TANK
None - 5
A32. Heavy tank - 5
A60. Medium tank - 3
A8. Armor unit - 1

A6. RELEASE POINT
None - 8
Four symbols - 1 each

A7. MONUMENT
None - 6
A30. Air defense artillery unit - 4
A48. Cooling tower - 2
A20. Vertical obstruction - 1

A8. ARMOR UNIT
A33. Attack aviation unit - 6
None - 4
A5. Light tank - 2

A9. ARTILLERY UNIT
A23. Aviation unit - 6
None - 3
Two symbols - 1 each

A10. COMMUNICATIONS CHECKPOINT
None - 9
A34. Air control point - 2
A45. Checkpoint - 1

A11. START POINT
None - 7
A49. Battle position - 2
Three symbols - 1 each

A12. GRAIN ELEVATOR
None - 8
A39. Target (nonstandard symbol) - 2
A37. Cavalry unit - 1

A13. RALLY POINT
None - 7
A39. Target (nonstandard symbol) - 4

A14. OBJECTIVE
None - 3
A49. Battle position - 2

A15. AIR CONTROL TOWER
None - 8
Three symbols - 1 each

A16. MISSILE IN AIR DEFENSE ROLE (LIGHT)
A63. Missile in air defense role (medium) - 5
None - 4
A31. Air defense gun (light) - 2

A17. AIR CAVALRY UNIT
None - 8
Four symbols - 1 each

A18. BUILDING
None - 10
A15. Air control tower - 1

A19. WINDMILL
None - 9
A69. Infantry unit - 2
A17. Air cavalry unit - 1

A20. VERTICAL OBSTRUCTION
None - 6
A7. Monument - 2
Three symbols - 1 each

A21. PICK-UP POINT
None - 7
Two symbols - 1 each

A22. BRIDGE
A69. Infantry unit - 10
None - 4
A3. Storage tank - 1

A23. AVIATION UNIT
A9. Artillery unit - 6
A33. Attack aviation unit - 3
None - 1
Two symbols - 1 each

A24. OUTDOOR THEATER
None - 10
A62. Radionavigation aid - 1

A25. ARMOR UNIT
None - 11

A26. HOLDING AREA
None - 10
A16. Missile in air defense role (light) - 1

A27. AIR PASSAGE POINT
None - 8
A6. Release point - 2
Three symbols - 1 each

A28. MECHANIZED INFANTRY UNIT (white on black)
A50. Mechanized infantry unit (black on white) - 5
None - 4
A25. Armor unit - 1

A29. AIRPORT
None - 6
Four symbols - 1 each

A30. AIR DEFENSE ARTILLERY UNIT
None - 5
A7. Monument - 2
A20. Vertical obstruction - 2
Two symbols - 1 each

A31. AIR DEFENSE GUN (LIGHT)
None - 5
A4. Offshore platform - 2
A16. Missile in air defense role (light) - 3
Two symbols - 1 each

A32. HEAVY TANK
None - 4
A60. Medium tank - 4
A5. Light tank - 3
A21. Pick-up zone - 1

A33. ATTACK AVIATION UNIT
A8. Armor unit - 4
A23. Aviation unit - 4
None - 1
Three symbols - 1 each

A34. AIR CONTROL POINT
None - 7
Five symbols - 1 each

A35. TARGET (standard symbol)
None - 9
Three symbols - 1 each

A36. LOOKOUT TOWER
None - 7
Four symbols - 1 each

A37. CAVALRY UNIT
A65. Armored cavalry unit - 5
None - 3
Three symbols - 1 each

A38. LIGHTHOUSE
None - 8
Three symbols - 1 each

A39. TARGET (nonstandard symbol)
None - 5
A13. Rally point - 4
Two symbols - 1 each

A40. PLAYING FIELD
None - 8
A47. Stadium - 2
A42. School - 1

A41. FALLS OR RAPIDS
None - 11

A42. SCHOOL
None - 8
Three symbols - 1 each

A43. POWER STATION
None - 8
A36. Lookout tower - 2
A29. Airport - 1

A44. SILO
None - 10
A36. Lookout tower - 1

A45. CHECKPOINT
None - 5
A49. Battle position - 4
Three symbols - 1 each

A46. UNCONFIRMED
None - 10
A18. Building - 1

A47. STADIUM
None - 7
A40. Playing field - 3
A56. FARRP - 1

A48. COOLING TOWER
None - 8
A30. Air defense artillery unit - 2
Two symbols - 1 each

A49. BATTLE POSITION
None - 3
A68. Observation post - 3
A45. Checkpoint - 2
Five symbols - 1

A50. LANDING ZONE
None - 9
Two symbols - 1 each

A51. DAM
None - 8
Three symbols - 1 each

A52. TRANSMITTING TOWER
None - 4
A62. Radionavigation aid - 4
A9. Artillery unit - 6
Two symbols - 1 each

A53. ATTACK POINT
None - 8
A34. Air control point - 2
A4. Offshore platform - 1

A54. RADAR REFLECTOR
None - 9
Two symbols - 1 each

A55. WATER TOWER
A3. Storage tank - 9
None - 1
Two symbols - 1 each

A56. FARRP
None - 8
Three symbols - 1 each

A57. CEMETERY
None - 6
A61. Church - 2
Two symbols - 1 each

A58. MECHANIZED INFANTRY UNIT (black on white)
None - 5
A28. Mechanized infantry unit (white on black) - 5
Two symbols - 1 each

A59. STEEPLE OR SPIRE
None - 10
A1. Chimney or smokestack - 1

A60. MEDIUM TANK
None - 5
A32. Heavy tank - 5
A5. Light tank - 2
A21. Pick-up point - 1

A61. CHURCH
None - 5
A63. Missile in air defense role (medium) - 2
A67. Air defense gun (medium) - 2
Two symbols - 1 each

A62. RADIONAVIGATION AID
None - 7
A52. Transmitting tower - 2
A67. Air defense gun (medium) - 1
Three symbols - 1 each

A63. MISSILE IN AIR DEFENSE ROLE (MEDIUM)
None - 4
A16. Missile in air defense role (light) - 2
A61. Church - 2
Three symbols - 1 each

A64. RAILROAD STATION
None - 10
A65. Armored cavalry unit - 1

A65. ARMORED CAVALRY UNIT
None - 5
A37. Cavalry unit - 3
Two symbols - 1 each

A66. OBSERVATION POST
None - 6
A49. Battle position - 3
A45. Checkpoint - 2
Four symbols - 1 each

A67. AIR DEFENSE GUN (MEDIUM)
A61. Church - 4
None - 3
A31. Air defense gun (light) - 2
A63. Missile in air defense role (medium) - 2
A23. Aviation unit - 1

A68. MINE
None - 8
Three symbols - 1 each

A69. INFANTRY UNIT
Bridge - 10
Windmill - 4

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APPENDIX 4. SURVEY BOOKLET FOR STUDY TWO (SYMBOL ASSOCIATION STUDY)

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MAP SYMBOL STUDY

IL SYMBOL ASSOCIATION

JULY 1982

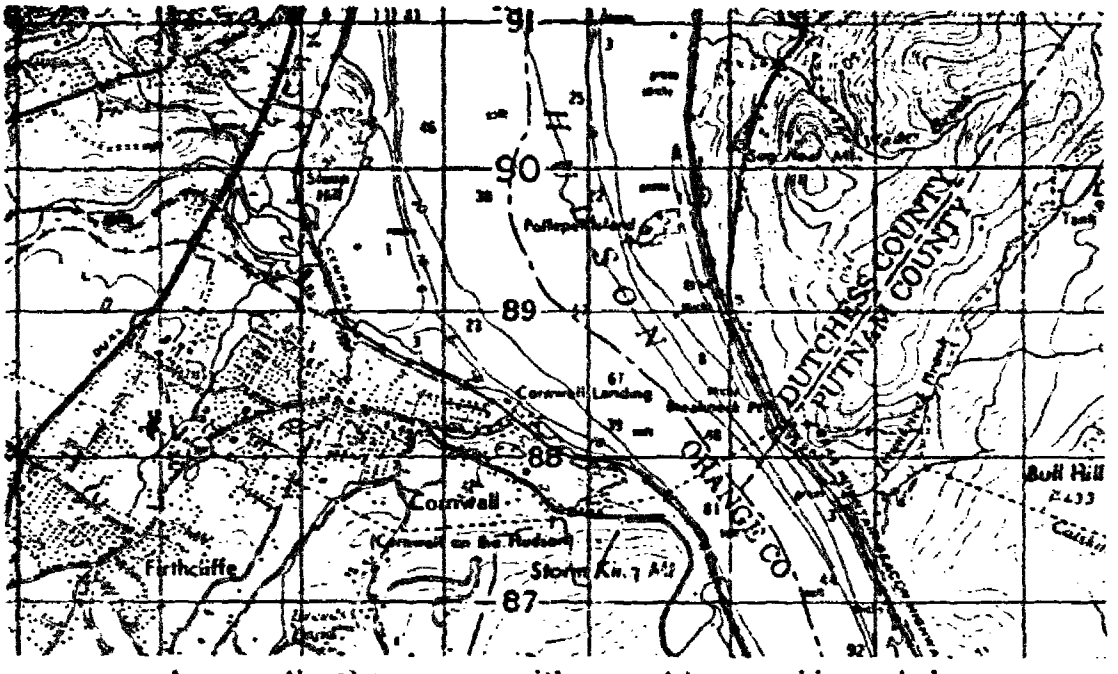
ANACAPA SCIENCES, INC.
P. O. DRAWER Q, SANTA BARBARA, CA 93102
TELEPHONE (805) 966-615

PURPOSE OF THIS STUDY

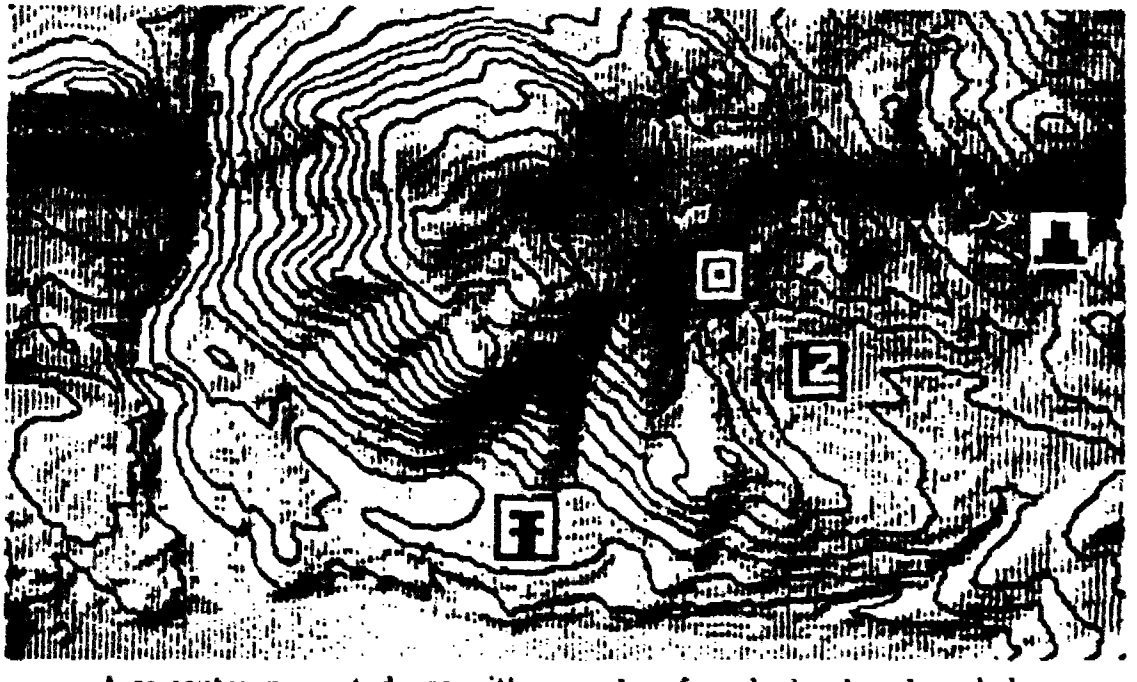
The purpose of this study is to determine how readily symbols that will be used in computer-generated maps can be associated with their meanings. As background, the Army Avionics R&D Activity is developing a computer-generated map display system for use in Army helicopters and other tactical vehicles. The system will be small and lightweight, yet it will have extensive capabilities. The computer-generated map will be displayed on a TV screen and will move to provide a continuous update of the vehicle's present position and the surrounding area. The vehicle operator will be able to annotate the map with tactical data before and during the mission. Map features, such as scale, contour interval, relief shading, masked routes and other information, will be selected for display by touching buttons.

The symbology for the computer-generated map display will be chosen to meet the specific requirements of Army aviators and other users rather than copying it from existing paper maps. For example, new types of symbols are needed since electronic displays are not always capable of presenting information in the same detail as paper maps. The difference in detail that is obtainable with paper and computer-generated maps is shown on the adjacent page.

Your participation in this study is important to the development of the map display system. Your help is needed in determining the best shape for symbols to convey their meanings accurately.



A conventional paper map with current topographic symbols.



A computer-generated map with examples of newly developed symbols.

WHAT YOU SHOULD DO

Your task will consist of attempting to match symbols with their intended meanings. Your answers, and those of other respondents, will indicate how well each of the symbols is associated with its intended meaning.

Please complete the personal information sheet before you begin the matching task. When you have completed this sheet, read the instructions on the next page. If you find that you are tired or your attention has diminished, please stop work on the task and return to it when you are refreshed.

INSTRUCTIONS

1. Look at the first symbol on the next page. (This symbol is designated A1).

2. Look at meanings, one-by-one, on the page that is adjacent to the symbols.

3. Select the one best meaning for the symbol. You may choose to use the same meaning with more than one symbol. It is not necessary to use all of the meanings.

4. Write the numeric code for the meaning that best matches the symbol on the appropriate line of the blue answer sheet. If you feel that none of the meanings matches the symbol, write "none" on the appropriate line of the answer sheet.

5. Repeat these steps for the second symbol (A2). Continue performing these steps until you have compared every symbol with the list of meanings.

6. When you have completed this task, turn to page seven.

SYMBOLS


A1
A2
A3
A4
A5
A6
A7
A8
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A11
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A67
A68
A69

MEANINGS

The following meanings are listed in alphabetical order:

1. Air Cavalry Unit
2. Air control point
3. Air Defense Artillery Unit
4. Airfield tower
5. Airport
6. Ammunition supply point for Army aviation
7. Antipersonnel mine
8. Antitank mine
9. Armor Unit
10. Armored Cavalry Unit
11. Artillery Unit
12. Assault crossing
13. Attack Helicopter Unit
14. Attack position
15. Aviation Unit
16. Battle position
17. Bridge
18. Cavalry Unit
19. Cemetery
20. Checkpoint
21. Chemical Unit
22. Chimney or smokestack
23. Church
24. Communications checkpoint
25. Cooling tower
26. Dam
27. Engineer Unit
28. Falls or rapids
29. FARP (forward arming and refueling point)
30. Fort
31. Full-tracked armored personnel carrier
32. Grain elevator
33. Heavy tank
34. Holding area
35. Horizontal control point
36. Infantry Unit
37. Landing zone
38. Light gun in air defense role
39. Lighthouse
40. Light missile in air defense role
41. Light tank
42. Lookout tower
43. Mechanized Infantry Unit
44. Medical Unit
45. Medium gun in air defense role
46. Medium missile in air defense role
47. Medium tank
48. Mine tunnel
49. Monument
50. Mosque
51. Mountain pass
52. Objective
53. Observation post
54. Obstruction
55. Offshore platform
56. Open pit mine or quarry
57. Ordnance Unit
58. Outdoor theater
59. Pagoda
60. Passage point
61. Pickup zone
62. Playing field
63. Power station
64. Psychological Warfare Unit
65. Quartermaster Unit
66. Radar reflector
67. Radar station
68. Radio navigation aid
69. Railroad station
70. Rally point
71. Release point
72. Repair and Maintenance Unit
73. School
74. Signal Unit
75. Silo
76. Stadium
77. Start point
78. Steeple or spire
79. Storage tank
80. Tall building
81. Target
82. Topographic (combat service support activity)
83. Transportation Unit
84. Transmitting tower
85. Unconfirmed
86. Water (combat service support activity)
87. Water tower
88. Windmill

RETURN OF ANSWER SHEETS

1. If you desire, use the pink sheet that is attached to the answer sheets to make comments about the symbols or the study.

2. Return the booklet and completed answer sheets to the person who gave you the material.

3. That person will return them to Anacapa Sciences.

We would like to thank you for your participation in this study. Your responses will help to determine the best set of symbols for the computer-generated map display system.

APPENDIX 5. RESPONSE DISTRIBUTIONS FOR SYMBOL ASSOCIATION TASK

Response distributions for verbal definitions judged by survey participants to represent the candidate symbols are contained in this section. Responses for intended definitions are noted in bold face type. Single responses for two or more unintended definitions are combined into one category to simplify data presentation.

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A1. CHIMNEY OR SMOKESTACK
22. Chimney or smokestack - 15
25. Cooling tower - 1
63. Power station - 1

A2. PICK-UP ZONE
61. Pick-up zone - 17

A3. STORAGE TANK
86. Water (combat service support activity) - 9
29. FARRP - 2
87. Water tower - 2
79. Storage tank - 1
Two verbal definitions - 1 each
None - 1

A4. OFFSHORE PLATFORM
None - 8
55. Offshore platform - 2
Seven verbal definitions - 1 each

A5. LIGHT TANK
None - 5
41. Light tank - 4
34. Holding area - 3
Five verbal definitions - 1 each

A6. RELEASE POINT
71. Release point - 9
70. Rally point - 8

A7. MONUMENT
27. Engineering unit - 4
None - 4
55. Offshore platform - 3
63. Power station - 2
Four verbal definitions - 1 each

A8. ARMOR UNIT
None - 4
36. Infantry unit - 3
34. Holding area - 2
62. Playing field - 2
9. Armor unit - 2
Five verbal definitions - 1 each

A9. ARTILLERY UNIT
None - 9
56. Open pit mine or quarry - 2
Six verbal definitions - 1 each

A10. COMMUNICATION CHECKPOINT
24. Communications checkpoint - 17

A11. START POINT
77. Start point - 17

A12. GRAIN ELEVATOR
32. Grain elevator - 6
None - 5
86. Water (combat service support activity) - 2
Four verbal definitions - 1 each

A13. RALLY POINT
None - 5
46. Medium missile in air defense role - 3
38. Light gun in air defense role - 2
40. Light missile in air defense role - 2
Four verbal definitions - 1 each

A14. OBJECTIVE
52. Objective - 8
None - 6
57. Ordnance unit - 2
53. Observation post - 1

A15. AIRFIELD TOWER
29. FARRP - 6
42. Lookout tower - 5
4. Airfield tower - 4
87. Target - 1
None - 1

A16. MISSILE IN AIR DEFENSE ROLE (LIGHT)
40. Missile in air defense role (light) - 4
8. Antitank mine - 3
None - 3
45. Medium gun in air defense role - 2
Five verbal definitions - 1 each

A17. AIR CAVALRY UNIT
None - 5
12. Assault crossing - 4
35. Horizontal control point - 3
Five verbal definitions - 1 each

A18. TALL BUILDING
80. Tall building - 10
17. Bridge - 2
None - 2
Three verbal definitions - 1 each

A19. WINDMILL
88. Windmill - 7
None - 3
16. Battle position - 2
68. Radionavigation aid - 2
Three verbal definitions - 1 each

A20. VERTICAL OBSTRUCTION
80. Tall Building - 5
59. Pagoda - 2
None - 2
54. Vertical obstruction - 1
Seven verbal definitions - 1 each

A21. PICK-UP ZONE
64. Psychological warfare unit - 8
61. Pick-up zone - 7
None - 2

A22. BRIDGE
17. Bridge - 6
51. Mountain pass - 3
66. Quartermaster unit - 3
None - 3
Two verbal definitions - 1 each

A23. AVIATION UNIT
None - 9
56. Open pit mine or quarry - 2
Six verbal definitions - 1 each

A24. OUTDOOR THEATER
None - 9
58. Outdoor theater - 1
Seven verbal definitions - 1 each

A25. ARMOR UNIT (nonstandard symbol)
33. Heavy tank - 8
47. Medium tank - 3
9. Armor unit - 2
11. Artillery unit - 2
Two verbal definitions - 1 each

A26. HOLDING AREA
34. Holding area - 7
None - 4
35. Horizontal control point - 3
44. Medical unit - 2
37. Landing zone - 1

A27. PICK-UP POINT
60. Passage point - 16
None - 1

A28. MECHANIZED INFANTRY UNIT (white on black)
None - 5
9. Armor unit - 2
45. Medium gun in air defense role - 2
43. Mechanized infantry unit - 1
Seven verbal definitions - 1 each

A29. AIRPORT
5. Airport - 15
Three verbal definitions - 3 each

A30. AIR DEFENSE ARTILLERY UNIT
None - 4
48. Mine tunnel - 3
16. Battle position - 2
58. Outdoor theater - 2
Six verbal definitions - 1 each

A31. LIGHT GUN IN AIR DEFENSE ROLE
38. Light gun in air defense role - 4
11. Artillery unit - 4
3. Air defense artillery unit - 3
46. Medium missile in air defense role - 2
None - 2
Four verbal definitions - 1 each

A32. HEAVY TANK
None - 8
33. Heavy tank - 3
Six verbal definitions - 1 each

A33. ATTACK AVIATION UNIT
None - 7
31. Full-tracked armored personnel carrier - 3
9. Armor unit - 2
74. Signal unit - 2
Three verbal definitions - 1 each

A34. AIR CONTROL POINT
2. Air control point - 6
1. Air cavalry unit - 4
12. Assault crossing - 3
10. Armored cavalry unit - 2
72. Repair and maintenance unit - 1
None - 1

A35. TARGET (standard symbol)
81. Target - 11
None - 1
Five verbal definitions - 1 each

A36. LOOKOUT TOWER
84. Transmitting tower - 4
4. Airfield tower - 3
None - 3
42. Lookout tower - 2
63. Power station - 2
Two verbal definitions - 1 each

A37. CAVALRY UNIT
None - 3
18. Cavalry unit - 2
74. Signal unit - 2
Five verbal definitions - 1 each

A38. LIGHTHOUSE
54. Obstruction - 4
84. Transmitting tower - 3
63. Power station - 2
68. Radionavigation aid - 2
39. Lighthouse - 1
None - 1
Five verbal definitions - 1 each

A39. TARGET (nonstandard symbol)
45. Medium gun in air defense role - 3
None - 3
15. Aviation unit - 2
40. Light missile in air defense role - 2
Seven verbal definitions - 1 each

A40. PLAYING FIELD
None - 5
62. Playing field - 3
84. Transmitting tower - 2
Seven verbal definitions - 1 each

A41. FALLS OR RAPIDS
28. Falls or rapids - 14
Three verbal definitions - 1 each

A42. SCHOOL
73. School - 10
74. Signal unit - 4
None - 1
Two verbal definitions - 1 each

A43. POWER STATION
None - 4
82. Topographic (combat service support activity) - 3
Ten verbal definitions - 1 each

A44. SILO
None - 5
25. Cooling tower - 3
75. Silo - 2
Seven verbal definitions - 1 each

A45. CHECKPOINT
20. Checkpoint - 17

A46. UNCONFIRMED
85. Unconfirmed - 16
None - 1

A47. STADIUM
76. Stadium - 6
None - 4
83. Transportation unit - 3
Five verbal definitions - 1 each

A48. COOLING TOWER
None - 5
78. Steeple or spire - 4
49. Monument - 4
Six verbal definitions - 1 each

A49. BATTLE POSITION
16. Battle position - 14
None - 1
Two verbal definitions - 1 each

A50. LANDING ZONE
37. Landing zone - 17

A51. DAM
26. Dam - 6
None - 5
Six verbal definitions - 1 each

A52. TRANSMITTING TOWER
52. Objective - 3
81. Target - 3
None - 2
Seven verbal definitions - 1 each

A53. ATTACK POSITION
14. Attack position - 4
4. Airfield tower - 3
None - 3
8. Antitank mine - 2
13. Attack helicopter unit - 2
Four verbal definitions - 1 each

A54. RADAR REFLECTOR
None - 5
17. Bridge - 4
51. Mountain pass - 4
Four verbal definitions - 1 each

A55. WATER TOWER
87. Water tower - 15
Two verbal definitions - 1 each

A56. FARRP
None - 6
1. Air cavalry unit - 2
13. Attack helicopter unit - 2
Six verbal definitions - 1 each

A57. CEMETERY
19. Cemetery - 13
None - 1
Three verbal definitions - 1 each

A58. MECHANIZED INFANTRY UNIT (black on white)
44. Medical unit - 5
None - 4
10. Armored cavalry unit - 3
Five verbal definitions - 1 each

A59. STEEPLE OR SPIRE
76. Stadium - 4
49. Monument - 2
73. School - 2
74. Signal unit - 2
78. Steeple or spire - 1
None - 1
Five verbal definitions - 1 each

A60. MEDIUM TANK
None -7
47. Medium tank - 3
62. Playing field - 3
Four verbal definitions - 1 each

A61. CHURCH
23. Church - 14
Three verbal definitions - 1 each

A62. RADIONAVIGATION AID
None - 5
30. Fort - 3
56. Open pit mine or quarry - 2
Seven verbal definitions - 1 each

A63. MISSILE IN AIR DEFENSE ROLE (MEDIUM)
46. Missile in air defense role (medium) - 4
3. Air defense artillery unit - 2
63. Power station - 2
80. Windmill - 2
None - 1
Five verbal definitions - 1 each

A64. RAILROAD STATION
69. Railroad station - 14
Three verbal definitions - 1 each

A65. ARMORED CAVALRY UNIT
None - 6
10. Armored cavalry unit - 4
Seven verbal definitions - 1 each

A66. OBSERVATION POST
53. Observation post - 17

A67. AIR DEFENSE GUN (MEDIUM)
None - 4
11. Artillery unit - 3
45. Air defense gun (medium) - 2
3. Air defense artillery unit - 2
84. Transmitting tower - 2
Four verbal definitions - 1 each

A68. MINE TUNNEL
48. Mine tunnel - 6
None - 5
56. Open pit mine or quarry - 4
Two verbal definitions - 1 each

A69. INFANTRY UNIT
None - 7
36. Infantry unit - 1
Nine verbal definitions - 1 each